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THE COGNITIVE COMPLEXITY OF EVENT-DRIVEN REPLANNING:
MANAGING CASCADING SECONDARY DISRUPTIONS
IN AEROMEDICAL EVACUATION PLANNING

By

Marie E. Walters, Ph.D.

The Ohio State University, 1996

Professor David D. Woods, Adviser

Event-driven replanning is a dynamic process that adjusts plans in progress in response to unanticipated events. When an unanticipated event occurs, it disrupts the plan in progress by creating new demands with accompanying constraints that must be satisfied. The task becomes a constraint satisfaction problem that sometimes requires planners to negotiate to manage or relax constraints while they shuffle and reallocate resources that are already committed as part of the plan in progress. Revising the allocation and distribution of these resources changes the plan in progress and causes secondary disruptions with accompanying constraints. The types of secondary disruptions that occur are dependent on the resources that are revised. Each

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The purpose of this research was to understand the strategies that people use in the event-driven replanning process. The crux of the study centered around three directly observed cases of practitioners actually engaged in the event-driven replanning process in aeromedical evacuation. An in depth protocol analysis was performed on each of the three cases.

The results showed that constraints drive the event-driven replanning process. Planners use multiple strategies to identify and manage constraints to devise successful plans. Planners utilize a primarily depth first approach to plan development. They rely on recognition, using a case-based strategy which is augmented with opportunistic and hierarchical planning strategies. Planners also rely heavily on their ability to negotiate to manage or relax constraints during the event-driven replanning process. A surprising result was that planners did not consider minimizing secondary disruptions as a part of their planning strategy. Instead, they concentrated on accommodating the primary disrupting event and opted to manage the secondary disruptions that might ensue The results of this research can be used to design more effective automated tools to support the complex event-driven replanning process.

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THE COGNITIVE COMPLEXITY OF EVENT-DRIVEN REPLANNING: MANAGING CASCADING SECONDARY DISRUPTIONS IN AEROMEDICAL EVACUATION PLANNING

DISSERTATION

Presented in Partial Fulfillment of the Requirements for

the Degree Doctor of Philosophy in the Graduate

School of the Ohio State University

By

Marie E. Walters, M.S.

*****

The Ohio State University
1996

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ABSTRACT

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This dissertation is dedicated to Alice Cardozo, who even in the face of pancreatic cancer, taught me that joy and contentment come from within, not external circumstances. The light from your heart illuminates me. I know you are a gift from God and I am eternally grateful.

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Research Publication (maiden name: Gomes)

1. Cook, R., Woods, D., Walters, M., & Christoffersen, K. (1996). "The cognitive systems engineering of automated medical evacuation scheduling and its implications" In Proceedings of the 3rd Annual Symposium on Human Interaction with Complex Systems. (pp. 202-207), Dayton, OH.

2. Spravka, J. J., Gomes, M. E., Lind, S., & Zehner, G. (1994). "A human factors evaluation of the MH-60 PAVE-HAWK helicopter cockpit". (Report No. AL/CF-TR-1994-0056). Wright-Patterson Air Force Base, OH. Armstrong Laboratory

3. Spravka, J. J., Gomes, M. E., & Lind, S (1994). "Tools for automated knowledge engineering (TAKE) system evaluation methodology." (Report No. AL/CF-TR-1994-0113). Wright-Patterson Air Force Base, OH. Armstrong Laboratory.

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LIST OF ABBREVIATIONS

ACLS	Advanced Cardiac Life Support
AEC	Aeromedical Evacuation Clerk
AFA	Air Force Academy
AFB	Air Force Base
AP	Attending Physician
APES	Aeromedical Patient Evacuation System
ASTF	Aeromedical Staging Treatment Facility
CONUS	Continental United States
CP	Command Post
CTL	Controller
DMRIS	Defense Medical Regulating Information System
DO	Duty Officer
EMI	Electro-Magnetic Interference
ER	Emergency Room
FCC	Flight Clinical Coordinator
GPMRC	Global Patient Movement Requirements Center
MCD	Medical Crew Director

MTF	Medical Treatment Facility
Msn	Mission
PMR's	Patient Movement Requests
PVCs	Pulmonary Ventricular Contractions
RON	Remain Over Night
RP	Receiving Physician
SL	Shift Leader
SG	Surgeon General

CHAPTER 1

INTRODUCTION

1.1 Overview

Technology has spawned automated systems that schedule and plan complex dynamic processes more quickly and more efficiently then ever before. Sophisticated algorithms and increased computing power afford more effective and efficient utilization of resources, increase productivity, and ultimately sustain system complexity. However, what happens when plans are in motion, resources are committed, scheduled activities are underway, and an unanticipated event occurs?

Current literature on planning falls short of providing an answer to this question that will sustain planning in real world, complex environments. One of the primary reasons for this shortcoming is that the bulk of the planning research performed in the past focused on plan generation; i.e. developing a plan or scheduling events to accomplish some future activity.

More recently, researchers have begun to delve into the more dynamic aspects of planning where plan generation and plan execution coexist. Reactive

planning and plan repair are two of the more common approaches to dynamic planning. However, the environments in which reactive planning models are tested have been sparse, sedate, and void of any real world complexity. In addition, although recent research on plan repair has shown promise, the models used to study this approach continue to focus on static information and off-line repairs. As such, this research offers a different approach to understanding planning in complex, real world environments by studying how people replan ongoing activities in response to unanticipated events.

The basis for the current research was an ethnographic study of the Department of Defense Aeromedical Evacuation System. The study was comprised of direct observations of both routine and critical events, interviews, and retrospective critical incident reports that were collected over an eighteen month period. The crux of the study centers around three directly observed cases of practitioners actually engaged in the event-driven replanning process. An in depth protocol analysis was performed on each of the three cases. Results from this study, coupled with previous literature on planning were used to answer the fundamental question of this research: "How do people adapt plans in progress to respond to unanticipated events in complex, dynamic environments"?

1.2 Description of Event-Driven Replanning

A plan is underway to transport ill and injured military patients at various locations to appropriate medical treatment facilities around the world. Medical personnel, flight crews, and equipment have been assembled and dispatched to transport these patients. While operational personnel are monitoring this plan in progress, a new requirement emerges to provide immediate transport for a seriously ill patient who requires emergency medical treatment in another state. Multiple players collaborate to modify the plan in progress to transport the urgent patient to the appropriate medical treatment facility. A plan begins to take shape but is continually revised as additional data emerges and new or conflicting constraints arise. Diverting an aircraft to pick up the urgent patient disrupts the itineraries of the patients on board and those scheduled to be picked up by the diverted aircraft. As such, not only must a plan be generated to handle the unanticipated event, but itineraries for disrupted patients must also be replanned in order to successfully implement the overall revised plan. Later, new information on the urgent patient's status indicates a secondary medical condition which requires special in-transit medical care. Providing this care will significantly delay the patient's arrival at the destination and cause additional disruptions. Numerous participants interact to manage these issues and disruptions. Multiple activities and lines of reasoning emerge and intertwine as the situation unfolds and new information comes in over time. Issues are apparently resolved only to reemerge as new data arises. A

distributed process of discovering and accommodating multiple interacting constraints takes place as the participants collaborate to form and carry out a workable revised plan in real time. This is event-driven replanning.

Event-driven replanning presupposes a detailed existing plan or schedule that is based on projections of future demands and resources. Event-driven replanning is a dynamic process that adjusts plans in progress in response to unanticipated events such as urgent patient movement requests or unexpected loss of resources. When an unanticipated event occurs, it disrupts the plan in progress by creating new demands with accompanying constraints that must be satisfied. The task becomes a constraint satisfaction problem that sometimes requires planners to negotiate to manage or relax constraints while they shuffle and reallocate resources that are already committed as part of the plan in progress. Revising the allocation and distribution of these resources changes the plan in progress and causes secondary disruptions with accompanying constraints. The types of secondary disruptions that occur are dependent on the resources that are revised. Each resource that is altered will create different side effects that can ripple throughout the plan in progress and jeopardize future activities. These side effects or secondary disruptions throw the plan out of alignment and require planners to repair the plan and subsequently get the revised plan back on track (See Figure 1).

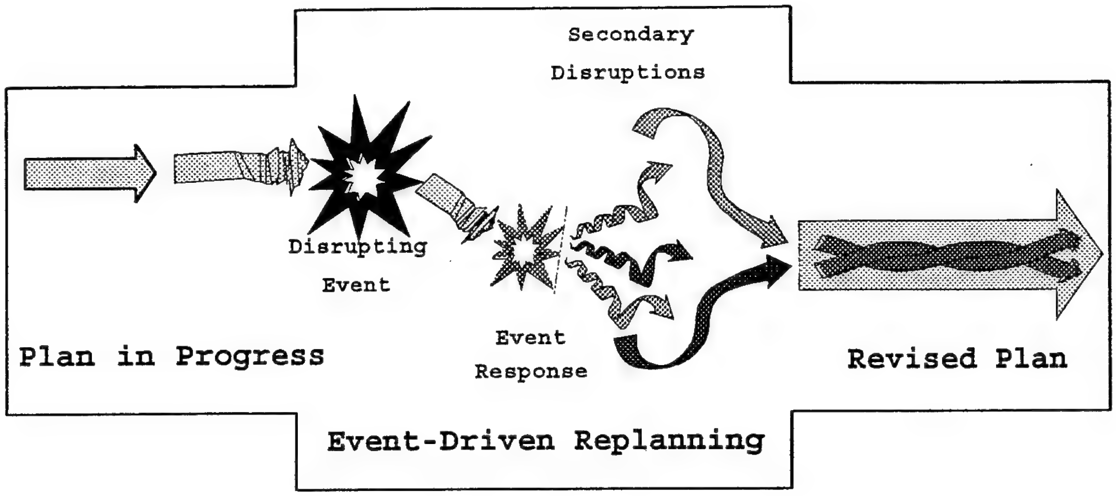

Figure 1. Event driven replanning. Disrupting events in the world initiate the event driven replanning process. The response to a disrupting event causes secondary disruptions that ripple throughout the plan in progress. Planners must manage these secondary disruptions and develop a plan to minimize their effects.

Once a plan is in motion; that is, when the planned for activities have commenced and resources have been committed, there are costs associated with changing the plan and "uncommitting" those resources. The cost of changing a plan in motion and uncommitting and recommitting resources can have far reaching effects. Replanning costs time and effort to mission planner, it costs money, resources, and potentially the reputation of the aeromedical evacuation system, it costs service providers time, effort, and paperwork, and lastly it can affect the timeliness of patient's receiving medical treatment. Carnegie Group, Incorporated uses the term "Sliding Scale of Commitment" to describe the costs associated with changing plans at various points on the time horizon. The closer

you move toward the present time, the higher the level of commitment of resources. Ringer (1992) uses a physical example to describe the planning process. Imagine a planning horizon that stretches from zero to 100 where t_0= Now and t_{100}= Infinity. The closer the planned for activity is to 100, the more gaseous, or undefined the plan. In this gaseous state, plans can be changed or reshaped to meet the changing environment. As you move closer to t_0, the plan starts to become more viscous and displays properties that make it more difficult to shape or contain. At t_0, the plan is a solid, has its own definitive structure and changing it at this stage requires considerable effort. To avoid the costs associated with changing the plan in progress, planners try to devise plans to accommodate the initial disrupting event but leave as much of the original plan intact as possible.

Event-driven replanning is a complex process that requires planners to engage in real time problem solving to deal with the disrupting event, and to project and manage secondary disruptions. It incorporates the cognitive elements of planning, problem solving, mental simulation, disturbance management, and decision making.

1.3 Event-Driven Planning vs. Other Planning Models

There are several factors that not only differentiate event-driven replanning from other planning approaches, but also create significant challenges for designers who wish to automate or support the event-driven

replanning process. First, the focus of this research was on discovering how ***people*** perform event-driven replanning in complex, dynamic environments. Second, this study looked at ***plans in motion*** as opposed to plan generation or static plan repair. Not only is the world in which the plan is operating dynamic and ever changing, the plan itself is moving and progressing to achieve multiple goals. Third, there is a ***cost of commitment***. Event-driven replanning involves uncommitting resources that have been previously committed. This disrupts the plan in progress which produces secondary disruptions which incur associated costs. Fourth, the context in which this study took place was a complex dynamic environment where ***information emerged and changed over time***. As such, the information required to create a successful plan was not available at the outset of the planning process. Information trickles in over time altering the nature of the plan/problem at hand. In typical planning models, the initial state is specified and the goal state is known. The role of the plan in those models is to chart a course from the initial state to the goal state. In event-driven replanning however, planners are required to commence the planning process under conditions where the initial and goal states may be unknown, incomplete or subject to change. As a result, operating in such an environment requires substantial adaptability, flexibility, and process knowledge to fill in the gaps when data is incomplete or prone to changes.

Currently, computational models and artificial intelligence methods do not possess the flexibility nor the adaptability that would be required to totally

automate the event-driven replanning process. As such, the event-driven replanning is a process that should be supported, but not automated.

1.4 Purpose of the Research

The purpose of this research was to uncover the cognitive demands that event-driven replanning imposes on practitioners and to understand the cognitive strategies and heuristics that they employ to cope with those demands. This was accomplished by identifying how planners in the Military Aeromedical Evacuation environment: 1) limit their search space to accommodate new disrupting events, 2) evaluate that search space for possible secondary disruptions, and 3) preserve plan integrity to the fullest extent in the face of those disruptions (i.e. keep as much of the original plan intact as possible).

The information in this report is based on direct observations of three event-driven replanning incidents in the aeromedical evacuation domain. A protocol analysis was used to identify and characterize the cognitive demands and strategies of event-driven replanning in this environment.

The aeromedical evacuation environment provided a natural laboratory to observe the event-driven replanning process *in situ*. However, the results of this research can be used to characterize demands and strategies in other dynamic planning environments such as job shop scheduling and airline dispatching (Szelke & Markus, 1994; Smith, McCoy, & Layton, 1995). The

knowledge gained from this research will provide valuable insight for developing aiding strategies to support this complex task.

1.4 Overview of the Paper

To facilitate the review of this research, the dissertation will be presented in seven chapters. **Chapter 2** presents an overview of the research related to planning and replanning. **Chapter 3** describes the complexity of the aeromedical evacuation domain and introduces the environment in which the observed incidents took place. It also includes brief descriptions of the facility, the players involved, and the cognitive artifacts utilized to perform event-driven replanning. **Chapter 4** is dedicated to methodological issues. It includes a description of the data collection activities and venues, the methods used to collect and document the activities of the cases along with a discussion of verbal reports and verbal behavior. This chapter concludes with a description of the verbal protocol analysis techniques utilized along with instructions for understanding the structure of the protocols. **Chapter 5** begins with a discussion of why the cases presented in this research were selected and why they are worthy of close examination, written overviews of each event-driven replanning incident describing the context in which the incidents took place, and a detailed description of the nature of each of the incidents. This chapter also provides complete protocol analyses along with descriptions of the interesting results of

each of the event-driven replanning incidents. **Chapter 6** synthesizes the results from each of the even-driven replanning incidents and presents conclusions and implications of these findings for cognitive engineering and aiding the cognitive components of event-driven replanning.

CHAPTER 2

RELATED RESEARCH

2.1 Disturbance vs. Disruption Management

Managing unanticipated activities or abnormal events in dynamic processes imposes cognitive demands on persons responsible for monitoring those processes. Disturbance management is used to refer to the procedure whereby process controllers attempt to diagnose a problem while continuing to maintain safe and effective process function. The distinction is made between a disturbance in a dynamic physical or engineered process such as nuclear power plant operation and a disruption in a non-physical process such as aeromedical evacuation planning. Traditionally, cognitive systems engineering principles have been focused on dynamic physical processes. Applying these principles to envisioned, non-physical processes is a neoteric venture for the field of cognitive systems engineering.

In dynamic physical processes, an abnormal event typically occurs when some component fails or ceases to function in the prescribed manner for the

context in which it is operating. Typically, when a fault occurs, system failure is not immediate, but instead system performance degrades over time. The monitored process is disturbed in that it continues to function albeit in a degraded state. A fault in a dynamic process produces a cascade of disturbances. These disturbances are the side effects or sources of influences resulting from the initial fault (Woods, 1994). Controllers are faced with the task of diagnosing the symptomatic effects in order to uncover the root cause of the problem. Unfortunately, a particular symptom may be a characteristic of many different faults. Disturbances propagate through the monitored process when systems are tightly coupled. The more the components or the activities are interleaved in a process, the greater the cascade of disturbances.

In dynamic activities that are not characterized by physical or engineered processes, such as event-driven replanning in the aeromedical evacuation domain, unanticipated events tend to have immediate effects. In addition, diagnosis does not come into play because the origin of the disruption is immediately apparent. Cascading disruptions and coupling result as multiple independent path problems depend on and contend for a limited set of resources.

Just as the goal of disturbance management is to diagnose the fault while preserving system integrity, the goal of disruption management is to accommodate the unanticipated event while preserving as much of the plan in progress as possible. In both cases, a form of mental simulation and hypothesis

generation come into play as operators and planners try to project the cascade of disruptions and diagnose the disturbances in order to adequately manage the consequences and identify the fault, respectively.

2.2 Computational Models

The field of artificial intelligence has provided tremendous insights into the hidden complexity of the planning process. For example, computer models that attempt to generate plans to move robots around objects in dynamic environments have been relatively unsuccessful. The hidden complexity inherit in designing such a system, as with all computational planning models, centers on the ability to keep track of disruptions that follow from an event. The dilemma arises from the conflicting desires to develop a system that is both robust and efficient in its reasoning about the future (Shoham, 1987). The following computational models are two of the more renowned approaches to plan generation.

2.2.1 Sacerdoti's ABSTRIPS Model

ABSTRIPS is a model that treats the planning process as a hierarchy of abstraction spaces. The abstractions serve as a means to discriminate between elements that are crucial to the success of the plan and elements that comprise the details that may become critical at the lower levels of the hierarchy. The highest level of abstraction generates a complete skeleton plan in which

unimportant details are not included. At each subsequent level of abstraction, critical details are maintained and incorporated and the less important details are bumped down to lower levels of the hierarchy. This occurs until a plan is identified that incorporates the details required to successfully achieve the goal. If a plan fails at one level of abstraction, the planner backtracks up the hierarchy and then takes a different path. The problem solving process is streamlined because the search heuristics will only investigate those details that higher levels identify as important.

2.2.2 *Wilensky's Planning Model*

Wilensky's approach to planning recognizes that human planning is a complex process composed of multiple interacting components. Wilensky proposed four components of an efficient planner; A Goal Detector, A Plan Proposer, A Projector, and an Executor. These components can be described in cognitive terms such as; recognition, situation assessment, mental simulation, and action respectively. Basically, Wilensky is describing an elaboration of the perception-action cycle.

2.3 Cognitive Models

2.3.1 *Hayes-Roth & Hayes-Roth's Opportunistic Model*

The Opportunistic Model is a cognitive model of planning. Hayes-Roth & Hayes-Roth define planning as "a predetermination of a course of action aimed

at achieving some goal". They, like Sarcedoti, also believe that planning occurs at multiple levels of abstraction. They extend that belief by adding that humans are able to plan at multiple levels of abstraction *simultaneously*. Humans have the ability to recognize opportunities to achieve other goals while planning for a particular goal. As opportunities are recognized the plan sequence may be altered and subsequently affect planning at any level of abstraction. Initial planning abstractions may highlight constraints at lower levels that will shift the focus of attention to that level. Similarly, lower level abstractions may uncover details or opportunities that suggest an alternative higher level abstract plan to replace the original plan. As such, planning is a heterarchical process that can proceed top down, bottom up, or across plan dimensions. This allows planners to capitalize on relationships in the environment and consequently yield more efficient plans.

2.3.2 Suchman's Situated Actions

Suchman (1987) views plans as resources for action. She states, that "While plans presuppose the embodied practices and changing circumstances of situated action, the efficiency of plans as representations comes precisely from the fact that they do not represent those practices and circumstances in all of their concrete detail" (p. 52). What differentiates plan generation from event-driven planning is that the former deals with anticipating future activities while the latter deals with reacting to situations currently occurring in the world.

Regardless of how successful a planner is at anticipating future activities, it would be impossible to predict and plan, in detail, for every possible outcome. As such, plans are inherently incomplete. Wilensky makes a similar point in the following statement: "...plans are continually revised in response to detected flaws and changes in the environment. In fact, since the planner is in principle detecting new goals all the time, the idea of a completed plan is only a relative notion" (Wilensky, 1983 p. 17).

2.3.3 Hammond's Case-Based Planning and Plan Repair

Case-based planning is based on the notion that planning is primarily a memory task. Case-based reasoning posits that people rely on past experiences to guide their actions in present situations. Human planning is case-based in that people use plans in memory as starting points to guide new planning activities (Hammond, 1990). As such, people never devise a plan from scratch. They always base a new plan on an old plan that has at least marginal similarities to the situation at hand.

Case based planners use knowledge of the world and effects of actions to assess a situation. They make use of memory (past experiences) whenever possible to help build new plans out of old plans. Successful plans are indexed by the goals they satisfy and the problems they avoid. Plan failures are indexed by the features in the world that help predict them. Knowing the paths that lead

to failure, enables planners to recognize the conditions that lead to the failure and consequently avoid going down that path again.

Hammond's (1990) research is focused on plan failure and plan repair. Hammond characterizes failures in terms of plan-goal interactions and indexes plan repairs by causal descriptions of the problems they solve. She has developed a specific vocabulary that provides a distinct causal description of plan-goal interactions to explain why a plan failed. This causal description will then be linked to a plan repair designed to deal with that particular plan/goal interaction failure.

2.4 Event-Driven Replanning vs. Plan Generation, Plan Repair, and Adaptive Planning

There are several factors which differentiate event-driven replanning from plan generation, plan repair, and adaptive planning. Event-driven replanning is not plan generation (Sarcedoti, 1974; Hayes-Roth and Hayes-Roth, 1979; Wilensky, 1981). Event-driven replanning deals with activities that are occurring right now, where as plan generation deals with activities projected to occur in the future. Event-driven replanning is more than simply plan repair. Hammond (1990) claims that the most powerful approach to plan repair is to have the planner explain and then debug any failures that are detected. In event-driven replanning as observed in aeromedical evacuation, failure to execute a plan properly is a serious, potentially life threatening issue whereas a failure executed by Hammond's case-based planner CHEF, might result in a

soggy batch of Szechwan beef and broccoli. The key point here is that failures cannot and do not drive the event-driven replanning process but rather constraints which impede the ability to successfully attain the goals at hand do. As such, just as a cased-based planner indexes successes and failures to guide future planning endeavors, aeromedical evacuation planners index techniques that allow them to successfully recognize and manage constraints to conduct future plan developments.

Models of reactive or adaptive planning are far from possessing the sophistication required to perform event-driven replanning in a complex environment. Current models claim to be reactive when robots can move freely through an unknown space without bumping into walls. Current models also claim to be dynamic when a robot can move blocks around the room with a mischievous baby on the loose (Schoppers, 1987; Ambros-Ingerson & Steel, 1988). Although advances have clearly been made with respect to creating more realistic representations of more dynamic and more complicated worlds, current artificial intelligence models still fall short of representing the complexity that actually exists in real world, dynamic environments.

CHAPTER 3

THE DOMAIN OF STUDY: MILITARY AEROMEDICAL EVACUATION

3.1 Introduction

The Department of Defense Aeromedical Evacuation (AE) System establishes policy, develops plans, and executes procedures for the transport of injured or ill military members and dependents of military members during peacetime, wartime, and contingency operations. Aeromedical evacuation combines the skills of mission planners, medical personnel, administrators, and aircrews who are dispersed in locations throughout the world.

3.2 The Aeromedical Evacuation Planning Processes

Aeromedical evacuation involves two processes: plan generation and event-driven replanning.

1. Plan generation constitutes the bulk of the activity of the aeromedical evacuation system. It is the daily planning of resources and demands that are

forecasted for the near term (2-5 day period). Plan generation consists of the following primary tasks:

(a) identifying and designating the most appropriate medical treatment facility available for a given patient;

(b) arranging the necessary equipment, medical attendants, and transportation required to provide effective in-transit patient care;

(c) planning the most efficient route to deliver patients to designated facilities.

2. Event-driven Replanning, which is the focus of this research, is a dynamic process that reacts to new information in the present. Event-driven replanning requires practitioners to perform all of the plan generation tasks **plus** manage the cascading disruptions that result as plans are rebuilt in real time. During event-driven replanning, practitioners must track and manage multiple threads of activity under time pressure. Threads of activity include: reexamining resource allocations, disrupting plans in progress, changing itineraries, and dealing with the consequences of those disruptions and changes. Weather, mechanical malfunctions, medical emergencies, airfield closures, and in-flight emergencies, etc. are potential disruptions which act as catalysts for event-driven replanning. This cases presented in this research dealt primarily with medical emergencies.

To a large extent, the planners responsible for arranging patient transport depend on other agents in the aeromedical evacuation system to provide

relevant and accurate information in order to generate feasible plans. Plan generation and event-driven replanning requires visualization of aircraft configurations, flight routes, hospital locations, etc. Planners must be able to track, organize, and manipulate information. They need to know or establish criteria for plan comparison.

3.3 The Complexity of Aeromedical Evacuation

The aeromedical evacuation system operates within a highly complex, distributed environment that by its very nature is time restricted, conflict rich, riddled with uncertainty, and high in risk. A distributed environment denotes an environment where information, authority, and accountability may reside with multiple people separated by either space or time. There are four characteristics that typify complexity and define the cognitive demands of an environment: dynamism, interconnectedness, uncertainty, and risk (Woods 1988).

1. Dynamism - A dynamic environment is one where information and events change over time. As such, information and events drive the planning, problem-solving and decision making processes in these environments. Event driven processes are characterized by time pressure, overlapping tasks, and sustained performance. The very nature of problems or the process itself may change at any point as new information is injected into the system. Patient movement requests (PMRs) are the primary drivers in the medical evacuation

system. PMRs can be entered into the system at any point and totally alter the evacuation plan in progress. For instance; imagine that an aircraft carrying 20 routine patients was scheduled to travel from point A to point B at 1500 hours. At 1445 hours an Urgent PMR (urgent denotes the highest priority for patient movement indicating a potential loss of life or limb situation) comes in with a patient that needs to go from point A to point Z. If the aircraft scheduled to depart at 1500 is the only aircraft available, then the 20 patients originally scheduled to go to point B will be delayed or rescheduled. Other events that can drive the evacuation process are; weather, airfields, and aircraft availability. Weather may cause airfields to close, delay flights, etc. Airfields can have radar problems, runway problems, etc. which makes them unsuitable for landing. Aircraft may break down or be configured in ways that preclude transporting certain categories of patients.

2. <u>Interconnectedness</u> - refers to the coupling of the components or agents that comprise the process. The degree of interconnectedness affects the range of disruptions that may occur and the consequences of those disruptions on the system. Competing goals can also result from interconnectedness as different geographical areas of responsibility (theaters) pursue locally relevant goals that conflict with the broader perspective of global goals. As indicated in the previous example, one disruption (an Urgent PMR) affected 20 other patients. In addition, conflicts exist within and between theaters as they try to achieve local goals with globally constrained resources.

3. <u>Uncertainty</u> - refers to the inability to completely anticipate future states and events. This can occur because of vague, faulty, or incomplete information, volatile circumstances, and fragile situations. The aeromedical evacuation environment is filled with uncertainty. Weather changes, planes break down, patients' conditions deteriorate unexpectedly, illnesses are misdiagnosed, disasters occur, etc.

4. <u>Risk</u> - refers to danger and the knowledge that situations could have dire consequences. The presence of risk implies choices and tradeoffs will have to be made. Medical evacuation deals with life and death situations.

As can be seen, aeromedical evacuation depends on detailed plans to coordinate the transport and care of patients around the world. The complex and distributed nature of aeromedical evacuation makes it a superb environment in which to study the cognitive characteristics of event-driven replanning. Aeromedical evacuation planners must adjust to changing events, manage the cascade of disruptions that ripple through the system in response to those events, solve problems, make decisions, and ultimately rebuild plans in real time.

Another important characteristic that underscores the complexity of the aeromedical evacuation environment is that it is physically and functionally distributed. Distributed environments result when information used in planning decisions, responsibility and accountability for making choices, and the ability to change course or override plans is scattered among different

individuals or units, and/or separated by space or time (Fischhoff and Johnson, 1990).

3.4 The Global Patient Movement Requirements Center

The Global Patient Movement Requirements Center (GPMRC) resides in a building on the flight line at Scott AFB in Belleville, Illinois. The GPMRC is co-located with the 375th Air Lift Unit Command Post to facilitate the coordination between airborne assets and patient movement. The walls of the small control room are covered with maps, status boards, equipment lists, and digital clocks. A big screen television is projected on the front wall and a door that permits easy access to Command Post is the focal point of the rear wall.

3.4.1 The Participants

Multiple personnel, dispersed in locations throughout the country, both on the ground and in the air, participate in the event-driven replanning process. The crew at the GPMRC consists of a Flight Clinical Coordinator (FCC), a Duty Officer (DO), and a Controller (CTL). They are responsible for planning and coordinating the activities required to transport the urgent patient. Other key players included the Aeromedical Evacuation Clerk (AEC), the Attending Physician (AP), the Receiving Physician (RP), the Medical Crew Director (MCD), and the crew of the Command Post (CP). The roles of each of the participants will be explained below:

Flight Clinical Coordinator (FCC) - is a flight nurse who is the chief validator of medical information. He/she monitors and trouble shoots all present missions with respect to patient care, advises the MCD, orchestrates Urgent and Priority requests, and ensures that all provisions have been made to meet the needs of each patient.

Duty Officer (DO) - is the mission planner. He/she checks system assignment of patients, and manually assigns patients and plans missions.

Controller (CTL) - monitors missions, updates status boards, and keeps Aeromedical Evacuation Clerks updated on mission status.

Command Post (CP) - group of individuals responsible for communicating with the flight crew and ensuring all aspects of the mission related to the aircraft and aircrew are taken care of. They handle flight plans, diversions, refueling, etc.

Medical Crew Director (MCD) - chief flight nurse onboard the aircraft and in charge of the airborne medical crew. The medical consists of 2 flight nurses (including the MCD) and 3 medical technicians.

Aeromedical Evacuation Clerk (AEC) - clerk at originating Medical Treatment Facilities responsible for submitting PMR's to GPMRC.

Attending Physician (AP) - doctor currently administering care to the patient at the originating MTF.

Receiving Physician (RP) - doctor who will receive the patient and be responsible for his or her treatment at the destination MTF.

3.4.2 Cognitive Artifacts

3.4.2.1 Computer Tools. Currently, aeromedical evacuation is supported by a computer based patient record keeping system known as the Defense Medical Regulating Information System (DMRIS) and a semi-automated scheduling system known as the Aeromedical Patient Evacuation System (APES). The DMRIS is designed to manage patient regulating and patient movement information. PMRs are initiated by AECs at local MTFs via the DMRIS. The DMRIS contains 97 fields of administrative and clinical data that are evaluated by qualified GPMRC personnel. It possesses a marginal degree of intelligence in that it restricts data entry in some fields and blocks progressing through fields when required entries have not been made. In addition, when the system detects an error, it highlights the field causing the problem. Unfortunately the system possesses minimal intelligence with regards to understanding the data input or checking for consistency between data fields. This task is performed by FCC's at the GPMRC. FCC's check over every PMR that comes into the GPMRC. At times, however, the DMRIS's limited intelligence creates unnecessary work and confusion. This occurs when an AEC wants to specify a particular medical treatment facility (which is common) outside of the DMRIS's programmed selection of venue. The DMRIS is programmed to send a patient to the closest facility that has the capability to suit the patient's need. Although this is a nice feature to have built into the system at most times, it is a major encumbrance whenever there is a patient requirement to deviate from this logic. As a result,

practitioners are forced to devise methods to trick the system, so that they will be "allowed" to enter the data that suits the patient's requirements instead of the DMRIS's logic.

Once the data has been accepted by the DMRIS, it must be evaluated for administrative and clinical validity. For example: Does the diagnosis correspond with the patient's vital signs and medical history? Once an FCC determines that the input is valid, the record is automatically passed to the Aeromedical Patient Evacuation System (APES). The APES then assigns the patient to one of the scheduled missions (this is the only "automation" that exists in the current system). Unfortunately, this system also possesses limited intelligence and is consequently unable to handle anything but the simplest movement requests. For instance; if the patient's origination and destination are not one-to-one matches with a scheduled mission, the APES will not assign the patient. The APES is not programmed to handle cases where patients would have to fly to one place, stay over night and then catch another flight the next day. As a result, the APES rejects these requests and they have to be done manually. Unfortunately, rejections are fairly common.

<u>3.4.2.2 Big Screen Television</u>. A big screen television, which is usually tuned to the weather channel, is projected on the front wall. Weather channel access allows the GPMRC staff to anticipate problems or delays by observing current weather activity and weather patterns that may be developing around the country.

3.4.2.3 Mission Status Board. A large mission status board occupies the right wall of the control room. It lists the aircraft, mission segments, airfields, times, and patient loads for each mission scheduled to fly that day. Typically there are between 4 and 6 missions flying in the continental United States every weekday. Different colored grease pencils are used to annotate changes and differing movement priorities on the status board. Patient movement requests (PMR's) are classified as; Routine - must be moved within 72 hours, Priority - must be moved within 24 hours, or Urgent - must be moved within 8 hours. Yellow is used to indicate changes to the original plan. For instance; if a plane takes off late, the revised time is written in yellow. Red and orange are used to indicate Urgent and Priority patients respectively. All other information is annotated in black. Bracketed lines are used to highlight important connections between mission segments. For instance; brackets are used to highlight pick-up and drop of points for Urgent and Priority patients. In addition, brackets are used to emphasize altitude restrictions. The affected mission segments are bracketed and the corresponding altitude limit is annotated above the line. Twelve digital clocks, marking the time at various world wide locations, are situated above the mission status board. The GPMRC schedules operates on Zulu time.

The mission status board provides mission planners with a store of useful information at a glance. It is the first place mission planners will look to seek alternative courses of action when unanticipated events arise.

3.4.2.4 Planning Map. A large map of the United States occupies the wall next to the DO's desk. The map has hundreds of pins anchored at the airfields where the planes can land. The DO plans routes by running a string from pin to pin and then measuring the distance by stretching the string out on a scale at the bottom of the map to determine distance in miles. He then refers to a conversion chart posted to the side of the map that allows him to convert miles into estimated flight times. The length of the string is the equivalent of a crew duty day. Consequently, if the DO runs out of string while trying to plan ("string") a mission, s/he knows that the intended plan will fail because it violates crew duty day limits. In fact, several DOs remarked that the map/string/chart system generally produces more accurate estimates of distance and time than the APES computer system.

3.4.2.5 Equipment Requirements Board. An equipment requirements board is situated next to the FCC's desk. It serves as a reminder of special equipment needs for the following days' flights.

CHAPTER 4

METHODOLOGY

4.1 Introduction

The data collected for the purpose of this research was accumulated over an eighteen month period. Data collection opportunities included numerous interviews and direct observations at various levels of the aeromedical evacuation domain. Several weeks were spent observing routine and emergency operations at the GPMRC. Observations were also made during a full scale Naval medical evacuation exercise at Camp Pendelton, CA. This provided an excellent opportunity to observe simulated wartime patient evacuation.

In addition, observations and interviews were also conducted onboard the C-9 Nightingale during actual aeromedical evacuation missions. This afforded the opportunity to experience aeromedical evacuation at "the sharp end" to gain a better understanding of the requirements and demands imposed on the medical crew and the patients. Observations and interviews were

conducted with AEC's at a regional MTF and a reserve squadron preparing for overseas patient evacuation. This broad exposure to the various facets of the aeromedical evacuation environment provided a deeper understanding of the domain which afforded an opportunity to see "the big picture".

The observations and interviews conducted during the exploratory and data collection phases of this research provided the basis for the analysis of the cognitive demands and strategies of event-driven replanning in the aeromedical evacuation environment. Observations afforded opportunities to capture the verbal behavior of practitioners engaged in actual event-driven replanning activities. Interviews were conducted to explain and confirm those activities observed during the event-driven replanning episodes.

The cases recorded in this study were directly observed by the author who was present during each episode to witness the event-driven replanning process in real time. As such, the author was able to not only record the verbal communications but also note the behavior and actions of participants as events unfolded.

4.2 Verbal Protocol

Verbal behaviors are situated expressions of a task related activity such as; communications between multiple people, requests for information, etc. They are the actual verbalizations that occurs in the performance of a task. Verbal reports, on the other hand, are verbal descriptions of a task provided by

the person performing the task. Verbal reports can be given concurrently - as the task is being performed, or retrospectively - after the task has been performed. Concurrent verbal reports are sometimes called "think aloud" protocols.

The conversations which formed the basis of the analysis used in this research consisted of the natural discourse that occurred between the participants of the GPMRC while engaged in the event-driven replanning process.

Fortunately, some of the conversations between members of the GPMRC and remote participants were conducted over a speaker phone so that the communication between both parties could be recorded. In all other cases, the conversations exchanged between parties over the telephone were communicated after the fact as the person on the telephone relayed information to the other members of the GPMRC. In addition, members of the GPMRC provided unsolicited verbal reports to explain events and activities as time permitted. On one occasion, a member of the GPMRC provided an unsolicited verbalization of a mental simulation. At other times, verbal reports were solicited by the author during gaps in activity and at the end of the episodes to clarify uncertainties in the data.

Since much of the activity and coordination required to devise a plan to transport the urgent patient occurred in parallel, it was impossible to capture every conversation that occurred among the five members of the GPMRC.

Consequently, the observations and recordings collected during this study focused on the principle participants; the FCC and the DO.

4.3 Analysis

The observations and recordings from this case were examined using a technique known as protocol analysis. Protocol analysis is used to identify and understand the cognitive aspects of a complex episode (Woods, 1993). The objective of protocol analysis is to lay out a problem solving episode from the point of view of the participants. The goal is to understand how a process evolves and is assessed through the eyes of the those involved. This requires understanding the perceptual and cognitive cues that activate knowledge, and how knowledge and goals guide the actions of the participants.

Complications inherent in the aeromedical evacuation environment create complexity across people and time. Understanding the behavioral aspects of a task is particularly difficult when the process involves multiple agents distributed in various locations throughout the country *and* in the air. This difficulty is magnified when multiple issues and activities began to overlap and intertwine as the situation evolved.

To cope with the difficulties of coordinating activities across people and time, a goal decomposition was used to structure the data for the protocol analysis used in this study. The goals were identified and decomposed as follows:

Goal - Verify Patient's Status

Goal - Arrange Transportation

Sub-goal - search for opportune aircraft

Sub-goal - search for plane to divert

Sub-goal - determine where to land

Sub-goal - arrange ground transportation

Sub-goal - modify mission/drop last stop

Sub-goal - modify mission/manage secondary disruptions

Goal - Manage Patient

Sub-goal - update patient status

Sub-goal - find destination MTF/RP

Sub-goal - search for medical attendant

Sub-goal - equipment requirement

Goal - Commit to the Plan

Sub-goal - administration

Sub-goal - enter plan into computer

The goal decomposition framework facilitated laying out the different activities and events to expose the cognitive elements in the protocols (Rasmussen, 1985). This entailed identifying the steps required to accomplish the goals, what data was acquired, how the situation was assessed, what knowledge was activated, and what triggered those acquisitions, assessments, and activations. The protocols revealed the connections between behaviors and

activities that led to either a decision, an action, or a request for additional knowledge. These connections are illustrated by tracing the perception-action cycle to expose how events in the world are picked up, how they trigger or shift different lines of reasoning, and how those lines of reasoning lead to intentions and action (Neisser, 1976). This provided a way to capture the mindset of the participants as they responded to new information, shifted lines of reasoning, and made decisions.

The observations and recordings of the verbal and non-verbal behaviors, verbal reports, and activities of the participants during this episode provided the basis for the protocol analysis.

An example of how the perception-action-cycle was used in this analysis, is shown in Figure 2.

Using the perception-action-cycle helped generate the layout that was used in the protocols. Reading horizontally across the bottom of the *data driven* and *knowledge driven* arcs of the cycle chronicled the activities that were taking place during the execution of a particular task. Reading horizontally across the top of the cycle, revealed the mindset of the participants. The dashed lines are used to indicate information coming into the GPMRC.

Although the example provided in Figure 2 is rather straight forward, a typical perception-action-cycle can become extremely convoluted as new information can enter in at any point in the cycle triggering multiple lines of reasoning or spawning new perception-action-cycles. Information infused at one

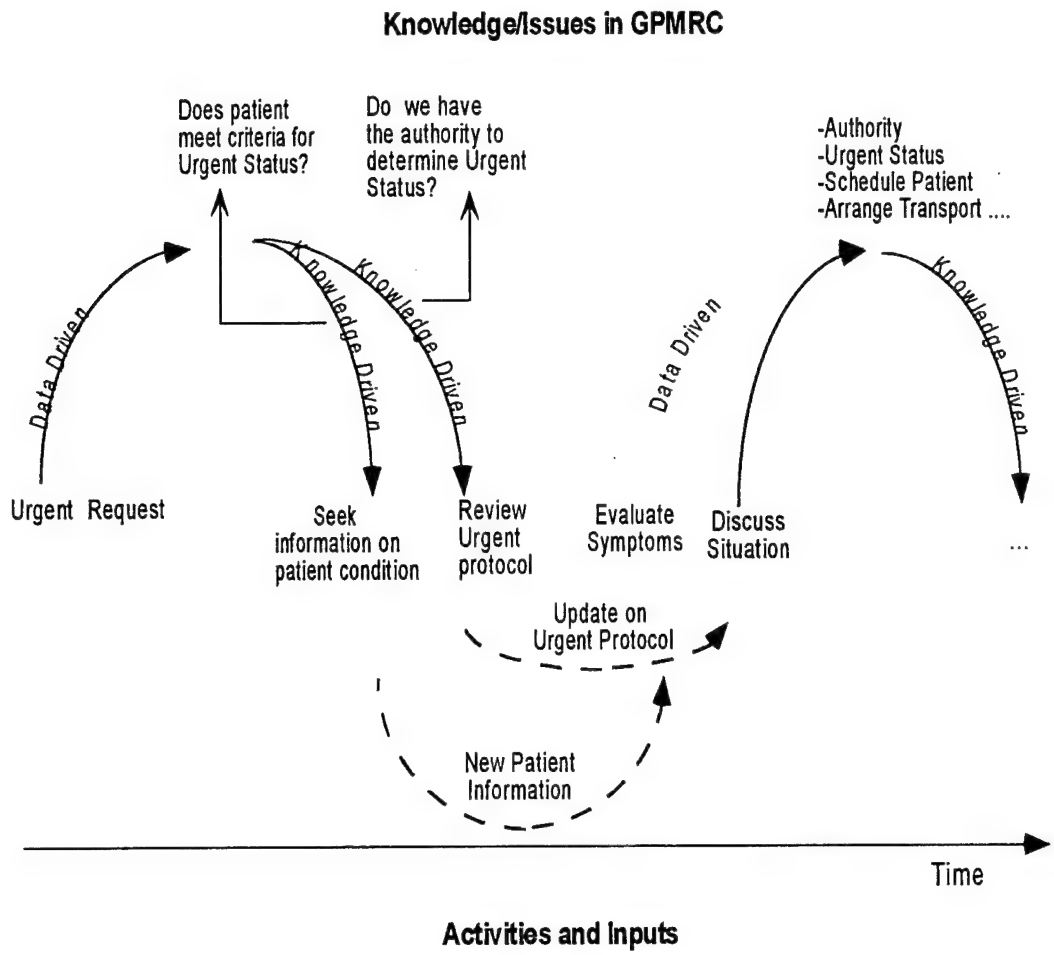

Figure 2. Perception - Action - Cycle for the Verify Urgent Status goal. The phone call from the AEC at Keesler AFB is the data driven event in the world that triggers this cognitive process. The call immediately activates the FCC & DO's knowledge of the criteria used to determine urgent status and their authority to make such a determination. They quickly recognize the need for additional information to begin processing this event. The DO begins questioning the AEC to learn more about the patient's condition while the FCC reviews policy on their authority to verify urgent status. The new information acts as a new trigger to activate the FCC & DO's medical knowledge so that they can process this information, assess the situation, and make a decision. They decide the situation is indeed urgent and they do have the authority to orchestrate the movement of the patient. This also serves as a trigger to begin arranging transport.

point can created its own mini-cycle until the final cycle is a composition of multiple mini-cycles. At times it can be difficult to ascertain where a cycle begins or ends. However, the crucial point is to identify the cognitive cues that activate knowledge and trigger a particular mindset. Understanding cue utilization and knowledge activation can then be used to comprehend the decisions or actions that follow.

4.4 Structure of the Protocol

The basic task flow of the protocol was derived from the goal decomposition. The protocol outlines the information flow and identifies the actors, actions, and outcomes associated with each task. It is from the FCC's and DO's points of view although activities continued "behind the scenes" for all other participants. The protocol strives to capture the mindset of the participants and the multiple threads of activity that emerge and intertwined as the situation unfolded. It displays how threads of activities were dropped and then reemerged at a later time or how tasks closed and were then reopened as loose threads became visible.

There are five columns of information on each page of the protocol. They are; 1) Time, 2) Event/Task, 3) Mindset, 4) Activity Inside GPMRC, and 5) Commentary. Reading row by row across the protocol allows the reader to follow and understand the behavioral and cognitive aspects of each event as the case progresses by identifying the when, what, who, where, and why aspects of

each activity. The protocol can also be read column by column. For instance; reading down the column labeled "Mindset" reveals the key participants' evolving interpretation of events as the episode unfolded. A brief description of the content of these columns follows:

1) Time - Identifies relative time steps that mark sequences of activity. The space allocated for each event does not represent actual time intervals but rather a subjective indication of the complexity of explaining a particular activity.

2) Event/Task - Describes the tasks and subtasks that are the focus of the activity during a given time period. The events and tasks are based on the goal decomposition (primary tasks equate to goals and subtasks are the same as subgoals). Reading down this column allows the reader to understand the basic flow of tasks throughout the episode.

To facilitate understanding the task flow, rectangles are used to indicate primary tasks and ovals are used to indicate subtasks. Tasks or subtasks can be shared by multiple agents or they can be split with each agent working on a different task or subtask at a time. When parallel activities occur, they are shown in sequence rather than in parallel (see Figure 3). Both subtasks are shown but only one comes to the foreground and is explained at a time. The background subtask will have a shaded background and dashed line connections. The foreground subtask will have a clear background and straight

line connections. The foreground subtask and all of its components will be shown to completion. Once the foreground subtask is completed, time reverts

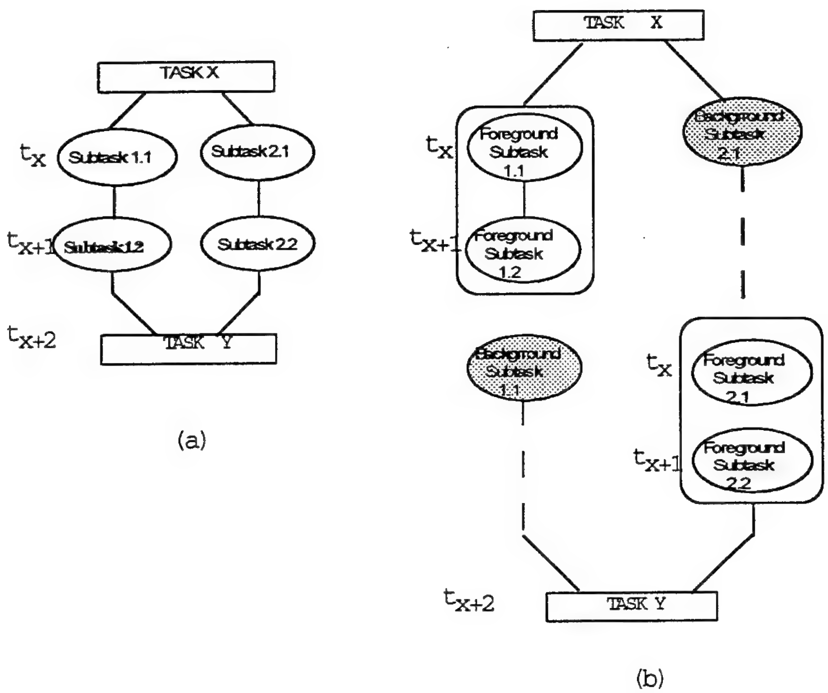

Figure 3. Task Flow. Drawing (a) depicts a Task X which is split into 2 separate subtasks. The subtasks and their associated steps occur in parallel. When the subtasks are completed, the parties rejoin and begin a new Task Y. Unfortunately, this parallel depiction of subtasks makes it very difficult to follow the mindset, activities, and comments associated with the respective subtask. To provide clarity, the protocol depicts the subtasks serially as in Drawing (b). In this drawing at t_x both subtasks 1.1 and 1.2 are shown but only subtask 1.1 is in the foreground and is shown in its entirety to time t_{x+1}. The drawing then goes back to time t_x and the subtask 2.1, which was previously in the background, comes to the foreground and is explained in its entirety to time t_{x+1}. The two subtasks then converge and activity commences on a new Task Y at time t_{X+2}.

back to the juncture where the original subtasks split. At that point, the foreground subtask moves to the background and the background subtask comes to the foreground and is shown to completion. In other words, only one task is described at a time form a particular time sequence. For example, the first task will be shown from time t_x to t_y. Then, time goes back to t_x to show what happened to the second task during that same t_x to t_y time frame.

3) Mindset - Specifies the inferred description of the participants' thought processes and intentions based on the information and event triggers.

4) Activity Inside GPMRC - Describes the actions that participants inside GPMRC took in response to the task under consideration and the information available at that time.

5) Commentary - Provides additional insight into the activities that took place during the respective time frame. There are 4 types of commentaries: 1) Unsolicited explanations are voluntary explanations of events or activities provided by participants of GPMRC to the author as an observer; 2) Solicited explanations are explanations that are the result of specific probes by the observer; 3) Unsolicited "think aloud" reports are voluntary verbalizations of mental simulations; and 4) Observer narratives are explanations provided by the author to put events in context for the reader.

Closure means the plan was established, coordinated, communicated, and accepted by all relevant participants.

CHAPTER 5

RESULTS

5.1 Introduction

The three cases presented in this chapter are actual event-driven replanning episodes that were directly observed at the GPMRC. Each case presents unique situations and problems which evoke distinct replanning strategies and techniques from practitioners thus providing different perspectives of the event-driven replanning process within the domain. The first case is an Urgent PMR which involves a kidney transplant patient at a civilian hospital with a potentially critical secondary medical condition that produces additional complications. The second case is also an Urgent PMR but it involves a hospital located outside of the CONUS which poses unique problems. Another interesting twist to this case is the emergence of an unusually compelling secondary disruption that warrants special consideration by the crew at the GPMRC. The third and final case involves correcting an equipment compatibility error previously committed for transporting a priority patient.

Although each case possesses unique characteristics, they also have interesting collective aspects that make them suitable candidates for case study evaluation.

First, these were all non-routine cases. Non-routine cases provide stressors that expose the strengths and weaknesses inherent in a system or process that are not visible during routine operations. Normal daily operations at the GPMRC consist of arranging and scheduling routine PMR's. Since planners are given 72 hours to arrange a routine patient, and 24 hours to arrange a priority patient, they fall under the realm of plan generation. Urgent patients, on the other hand, fall within the realm of event-driven replanning because patient movement must be arranged within a maximum of 8 hours. Because of the limited amount of time available to respond to an Urgent PMR, planners must replan and reallocate resources in real time.

Second, a number of complicating factors arose in each of these incidents which turned these cases into interesting expressions of cognitive adaptability and naturalistic decision making. Complicating factors included: conflicting diagnoses, special equipment and crew requirements, missing status board updates, error detection and correction, dealing with civilian and overseas MTFs, and managing complicated secondary disruptions.

Third, these are actual critical incidents that were observed in real time. Critical incident analysis has been recognized as an effective technique to explore cognitive aspects of performance in non-routine events (Flanagan, 1954;

Klein, Calderwood & MacGregor, 1989; Shattuck & Woods, 1994). Generally, critical incident investigations rely on practitioner's recollection of past events. In this case however, the critical incidents were actually witnessed by the author who is an Air Force officer as well as a specialist in cognitive engineering. The observer's experience provided both a familiarity with the organizational culture and the ability to recognize subtle cognitive components inherent in the process.

Although this research focuses on three particular non-routine cases, it is important to remember that these cases did not occur in isolation. Normal procedures, activities and operations continued to occur and provide the ever important context in which these incidents took place. Examining these cases in context is the only way to fully understand and appreciate the complexity of the event-driven replanning process.

In addition, it is important to keep in mind that although some of the demands and strategies documented in these cases may be unique to aeromedical evacuation in a peacetime environment, the cognitive activities involved are fundamental to the event-driven replanning process and hence can be applied to other dynamic scheduling and planning domains. As such, the information gained through the examination of these cases can be used to build a cognitive model of event-driven replanning that can sustain domains such as airline dispatching and manufacturing processes as well.

The next three sections in this chapter will walk through the details of each of the three cases. A brief description of each case is provided along with

the associated detailed protocol and a brief discussion of the interesting observations.

5.2 Case 1: Urgent Patient at a Civilian Hospital

5.2.1. The Context

It was a Tuesday afternoon, approximately 1530 CST. The day had been extremely hectic. Severe thunderstorms and tornado reports had forced the cancellation of 2 of the 4 scheduled flights for that day. The DO had been very busy trying to reschedule patients whose flights had been canceled. The FCC had spent a lot of time on the phone with several AEC's across the country trying to help them troubleshoot problems with the DMRIS. A partial shift change had occurred at 1500. The day shift DO was replaced by an evening shift DO. The normal daytime complement of three controllers were replaced by the standard evening complement of one controller. The DO was reviewing the itineraries of the rescheduled patients and the FCC was out of the room when the Urgent call was received.

5.2.2 The Urgent Call

An Urgent call from an AEC at Keesler Air Force Base in Biloxi, Mississippi at approximately 1530. The locations of all of the participants involved in this case are located in Figure 4. A civilian emergency room in Louisiana had a kidney disease patient reporting burning pain in his

stomach("hot belly") and a fever. The patient was a medically retired Navy male in his late thirties. He had had a kidney transplant 2 years prior and was

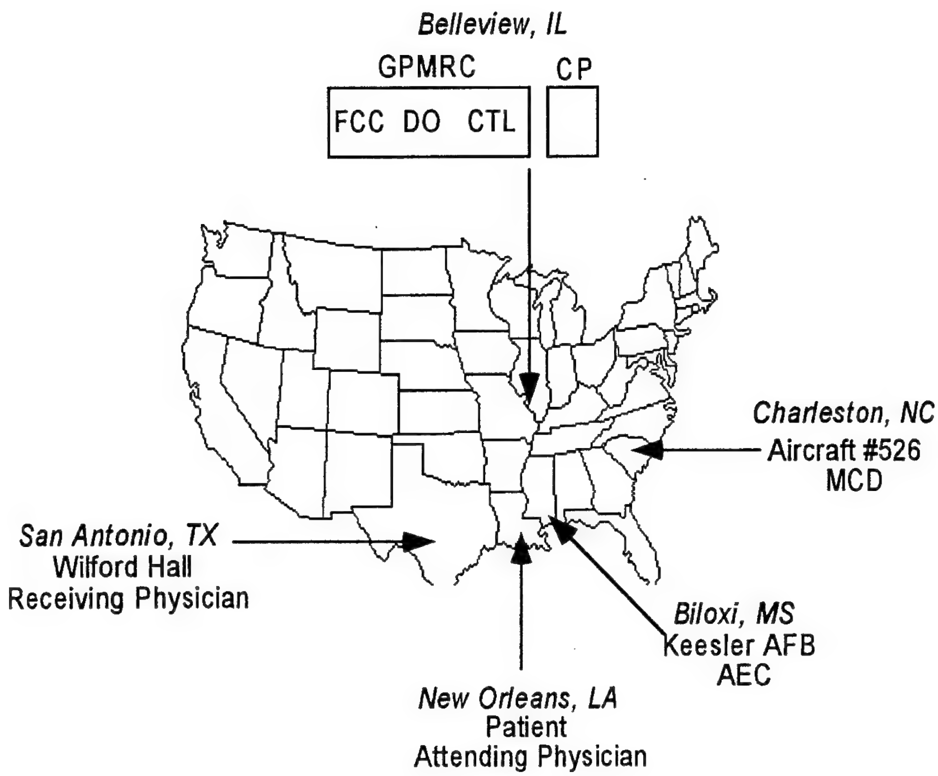

Figure 4. Location of Participants in Case 1. The call came from the AEC at Keesler AFB in Biloxi, MS. The patient was located just outside of New Orleans, LA. The destination medical treatment facility was Wilford Hall hospital in San Antonio, TX. GPMRC, which is co-located with CP at Scott AFB in Belleville, IL, orchestrated the replanning and patient movement. The MCD was on the Aircraft #526 that diverted to transport the patient.

currently taking an experimental drug. "Hot belly" is a possible indication of kidney rejection or abdominal infection possibly caused by the experimental drug. The AP specified patient transport to Wilford Hall Medical Center in San Antonio, Texas because the physicians there were familiar with the patient's case. The AP had made arrangements with a physician at Wilford Hall to accept the patient.

5.2.3 Protocol for Case 1 (presented on the following pages)

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_0	*Keesler AEC calls in Urgent PMR* *(unrequested information)*	Trigger →	DO takes the call	Normally the FCC handles Urgent calls but he is out of the room.
t_1	VERIFICATION		DO obtains additional information about patient status from Keesler AEC	DO writes all information down <u>on the back of an Urgent/ Priority Patient Worksheet</u>
t_2		Is this truly Urgent?	FCC and DO discuss patient status	FCC and DO activate their domain knowledge to determine Urgent patient status
t_3		Do we need approval?	FCC and DO discuss their authority to verify urgent status and thereby activate an evacuation plan	- FCC and DO consider calling and consulting with SG - Protocol (which is fuzzy) dictates consulting with SG to authorize "questionable" cases
t_4		CLOSURE VERIFICATION	FCC and DO decide patient is indeed Urgent	FCC and DO decide the case is straight forward they can authorize
	ARRANGE TRANSPORT	First plan/solution: Implement Default Plan	FCC states he will send a C-21 aircraft	Protocol says minimize cost and patient disruption. C-21 is smaller, cheaper to operate and has less restrictive landing requirements.

LEGEND

Italics - Incoming Information <u>Underline</u> - Artifacts UnSolicited Explanations Solicited Explanations Unsolicited **'think aloud '**reports

Case 1. Urgent Patient at a Civilian Hospital

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_5	*Keesler AEC reports Patient on IV and O_2* *(unrequested information)*		DO relay IV and O_2 information to FCC	DO says C-21 can't handle IV and O_2 requirements
t_6	Trigger	Second Plan/Solution: Divert a C-9		FCC explains diverting is cheaper and more efficient than launching the standby C-9 aircraft in terms of time and resources
t_7		Split Tasks for efficiency	DO and FCC discuss situation. Decide to divide ARRANGE TRANSPORT subtasks; Determine where to Land, and Search for Plane to Divert	DO still on phone with AEC
	ARRANGE TRANSPORT			FCC & DO decide to work the same main task but accomplish separate subtasks
t_8	FCC: Search for Plane to Divert; DO: Determine Where to Land		FCC and CTL look at <u>Status Board</u>	Find plane closest to patient: look at Msn# (denotes regions of country), and # of stops
t_9			FCC finds potential C-9 aircraft. Mission (Msn) #526	Assess negative effects on passengers: look at type and number of patients on plane

LEGEND

Italics - Incoming Information   <u>Underline</u> - Artifacts   UnSolicited Explanations   Solicited Explanations   ☆ Unsolicited '**think aloud** 'reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{10}	ARRANGE TRANSPORT		FCC and CTL search for additional information to test feasibility of potential plans	Consultation about patient load at planned final stop
t_8	FCC: Search for Plane to Divert; DO: Determine Where to Land	Find closest (minimize time) preferably military (cheaper) location	DO asks AEC if C-9 can land at Keesler AFB	Starts search here since call came from Keesler and DO still on phone with AEC
	AEC reports Keesler too far away *(requested information)*			
t_9	Trigger →	Generate additional options	DO looks at <u>Map</u> to generate other alternatives	
t_{10}			DO asks Command Post (CP) if C-9 can land at New Orleans NAS or New Orleans International Airport	
	CP reports: C-9 ***cannot*** *land at NAS* ***can*** *land at International Airport* *(requested information)*			DO states C-9 is very heavy and many airfields can't support it
t_{11}		CLOSURE Subtask - Determine Where to Land	DO says make arrangements. CP calls International Airport to arrange	DO - military must pay to use commercial airports
t_{12}	ARRANGE TRANSPORT; Search for Plane to Divert		- DO joins FCC to search for a plane to divert - CTL updates DO on Diversion Situation	

LEGEND

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Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{13}	ARRANGE TRANSPORT			
	Search for Plane to Divert		- FCC updates DO and seeks approval to divert Msn #526	
		(Apparent) CLOSURE Subtask - Search for Plane to Divert	- DO says do it	At this point FCC, CTL, & DO believe that Msn #526 is the aircraft that will transport the patient
t_{14}	Modify Mission: Drop Last Stop		FCC, DO, and CTL discuss whether to drop scheduled last stop on Msn #526 or divert and continue as scheduled	They consider crew duty day limits and decide that it would be close but not a violation to divert and then continue as scheduled
t_{15}		Take care of all patients affected by mission modification	- CTL looks at <u>Status Board</u> and announces that last stop (Shaw AFB) must be made because have a "special" patient to pick up - FCC announces that the "special" patient had canceled earlier	Normally a "special" designation means that the patient requires additional attention that may or may not be related to their condition (e.g. a young child traveling alone) <u>Status Board</u> had not been updated. There is confusion about the true state of requirements

LEGEND

Italics - Incoming Information <u>Underline</u> - Artifacts UnSolicited Explanations Solicited Explanations Unsolicited **'think aloud'** reports

Case 1. Continued

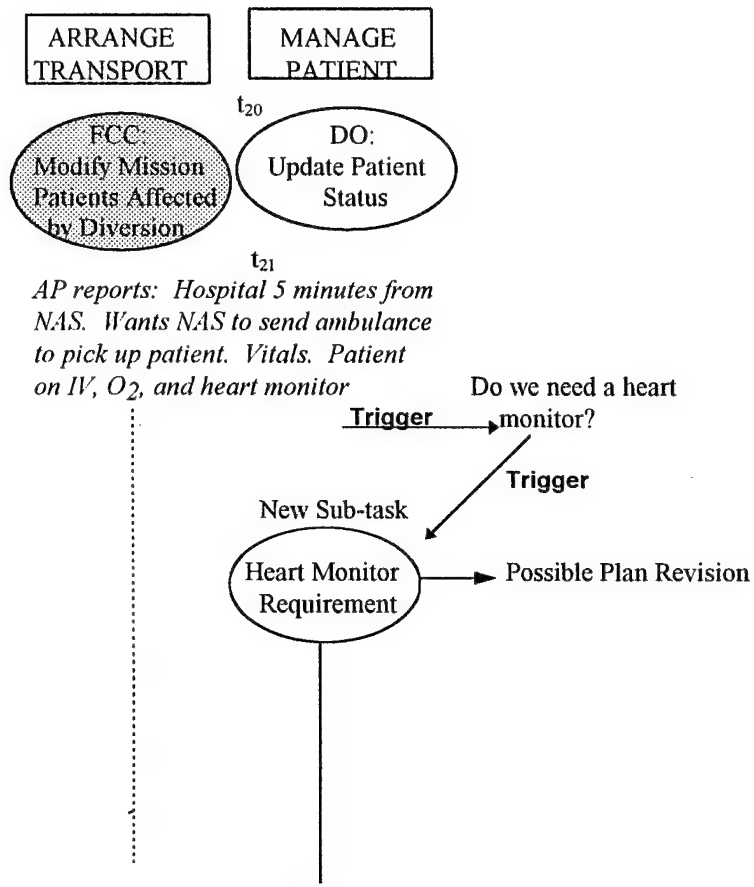
Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
	ARRANGE TRANSPORT			
t_{16}	Modify Mission: Drop Last Stop		FCC looks at notes and forms to verify that "special" patient had indeed canceled	"You mean to tell me we were going in there (Shaw AFB) for nothing?" - quote from DO
t_{17}			CTL double checks previous CTL's forms and announces that they still have one patient and an attendant to pick up at Shaw	
t_{18}		(Apparent) CLOSURE Subtask - Modify Mission: Drop Last Stop	DO says it would be better to drop Shaw because it would put the crew close to breaking crew duty limits	DO, FCC and CTL 'believe' they have reached closure but the issue will surface again later
t_{19}	ARRANGE TRANSPORT / MANAGE PATIENT			FCC & DO decide to work on subtasks from different main tasks
	FCC: Modify Mission: Patients Affected by Diversion / DO: Update Patient Status		DO calls AP to let him know what's going on with patient pick-up	Normally the FCC calls the AP, but DO calls to relay transport information and to confirm the patient's status
		Maintain awareness of multiple threads of activity	- DO asks "Why are we dropping Shaw?" - FCC replies "It's getting close to breaking crew duty limits."	DO time sharing tasks. He is waiting on the phone to speak to the AP and trying to keep up with "modify mission" subtask

LEGEND

Italics - Incoming Information Underline - Artifacts UnSolicited Explanations Solicited Explanations ☆ Unsolicited **'think aloud** 'reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary



DO apprises AP of transport situation. Tells him plane should be there in approximately 2 hours. DO asks AP: Distance to NAS? Can he transport patient to NAS? Patient's vitals? Any other equipment besides IV and O_2?

Heart monitor requirements drastically changes plan. Protocol dictates that heart monitor requires special cardiac care attendant

FCC starts brainstorming actions required to find a cardiac care nurse and transport him/her to New Orleans to attend the patient. Options include:
1) Send a C-21 to pick up the cardiac nurse and have them meet the C-9 in New Orleans
2) Have the C-9 divert to pick up the nurse first and then proceed to New Orleans to pick up the patient

LEGEND

Italics - Incoming Information Underline - Artifacts UnSolicited Explanations Solicited Explanations Unsolicited **'think aloud** 'reports

Case 1. Continued

Time	Event/Task		Mindset	Activity Inside GPMRC	Commentary
	ARRANGE TRANSPORT	MANAGE PATIENT			
	FCC: Modify Mission: Patients Affected by Diversion	DO: Heart Monitor Requirement	Can I drop the heart monitor requirement?	DO asks about requirements for heart monitor. Explains to AP that this requirement will change estimated patient pick-up time from approximately 2 to 4 hrs	DO & AP begin to negotiate heart monitor requirement
t_{22}	*AP says: PVC's rare. Waives monitor requirement. Move patient ASAP!*		Drop the heart monitor?		FCC explains that doctors do not like to follow directions from "Nurses." It is difficult for doctors (especially civilian) to accept that nurses run AE
			Trigger → Goal Conflict		FCC is in a bind. Protocol says delay patient transport until he can obtain qualified personnel to adequately care for the patient. However, the AP (who is a "professional" superior) has a different goal which is to move the patient to a suitable medical facility as quickly as possible.
t_{19}	FCC: Modify Mission: Patients Affected Diversion	DO: Heart Monitor Requirement		FCC and CTL continue coordinating mission modification; rerouting patients	

LEGEND

Italics - Incoming Information   Underline - Artifacts   UnSolicited Explanations   Solicited Explanations   ☆ Unsolicited **'think aloud** 'reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t20	ARRANGE TRANSPORT; FCC: Modify Mission Patients Affected by Diversion MANAGE PATIENT; DO: Heart Monitor Requirement		CTL calling AEC at Shaw AFB	CTL trying to ascertain the true status of patient requirements at Shaw AFB
t_{21}			FCC takes call from another AEC at Kelly AFB	FCC working multiple activities
t_{22}			FCC picks up an earlier problem and continues working it.	
t_{23}	FCC & DO: Heart Monitor Requirement	(Apparent) CLOSURE. Subtask - Heart Monitor Requirement No Plan Revision Required	DO explains heart monitor situation to FCC. They discuss it and decide to continue with original plan	FCC and DO could have requested a consultation with SG at this point. But it is unclear if they considered this option. Heart monitor could have been standard procedure for that emergency room
t_{24}	ADMINISTRATION	Takes care of administrative details	SL asks FCC if patient move and the new plan have been validated	Validation means FCC verifies that everything is OK. All inputs are complete and DMRIS & APES accepts the patient movement assignment

LEGEND

Italics - Incoming Information Underline - Artifacts UnSolicited Explanations Solicited Explanations ☆ Unsolicited '**think aloud**' reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{25}	ADMINISTRATION		FCC says "Yes, for all intents and purposes. I'll put in paperwork later." "If CP can get paperwork in (New Orleans International), then it's a go."	Paperwork is actually computer work
		All Constraints Satisfied?	FCC looks over <u>Form 14B (Manifest)</u> and discovers that they still have two patients to pick up and one patient to drop off at Shaw AFB who has been riding on the aircraft all day. Says have to make the stop	FCC wants to try to meet requirements for all patients effected by the diversion
	Trigger			
t_{26}	<u>ARRANGE TRANSPORT</u> FCC, DO, CTL: Subtask - Modify Mission: Drop Last Stop	(Re-open) Subtask - Modify Mission: Drop Last Stop	FCC, DO, and CTL discuss the ramifications of making the last stop. It might mean launching the alert C-9 because Msn #526 would break crew duty limits. This would delay patient pick-up by 4-5 hrs	Decision to drop or keep last stop resurfaces. DO focus - satisfy the urgent requirement, FCC focus - try to meet all requirements
		Goal Conflict		Goal conflicts exist between breaking crew duty limits vs. picking up the urgent patient vs. disrupting other patients
		(2nd Apparent) CLOSURE Subtask - Modify Mission: Drop Last Stop	- Decide to drop Shaw AFB stop - Duty officer concurs	

LEGEND

Italics - Incoming Information <u>Underline</u> - Artifacts UnSolicited Explanations Solicited Explanations Unsolicited '**think aloud**' reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{27}	DO: Update Patient Status	(Re-emergence) Subtask - Update Patient Status	DO calls RP to confirm physician will accept patient	Re-emerging tasks do not always require a trigger. They can be tasks that were interrupted and picked up again
t_{28}	COMMIT TO THE PLAN Enter Plan in Computer	Make the plan official	DO & FCC go over patient information to go into DMRIS	FCC does the actual data input. DO does information search. Both continue to do other tasks as required
		Trigger		
t_{28}			FCC asks if patient needs litter? DO says yes	FCC enters information into the 97 fields of DMRIS, when he gets to a field that he does not know, he asks the DO (since he took the call). If the DO doesn't know, he searches for the answer.
t_{29}		Get ahead on form filling data	DO looks up ICD9 codes	ICD9 codes identify various medical ailments. They are located in tomes. DO looks them up because he knows FCC will need them soon

LEGEND

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Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
	COMMIT TO THE PLAN Enter Plan in Computer	Get the computer to accept the plan	DO & FCC discuss most appropriate code to use	Determining the code that most accurately fits the patient's condition & matches DMRIS rules and expectations can sometimes become a guessing game
t_{30}	*AEC from another base calls for assistance. Needs help entering information into DMRIS for a different case* (unrequested information)	Distraction	FCC takes phone call from another AEC	The AEC is having problems getting DMRIS to accept a medical request from another case. FCC helps AEC "trick" the system to accept the request.
t_{31}	COMMIT PLAN Enter Plan in Computer ARRANGE TRANSPORT Ground Transportation	(Re-emergence) ARRANGE TRANSPORT	DO calls NAS to arrange ground transportation - hands off task to SL	FCC continues to input information into DMRIS as he helps AEC troubleshoot problems DO picks up the ARRANGE TRANSPORT task again to accomplish the Ground Transportation subtask. DO wants NAS to pick up patient at civilian hospital and transport to New Orleans Int'l

LEGEND

Italics - Incoming Information   Underline - Artifacts   UnSolicited Explanations   Solicited Explanations   ☆ Unsolicited **'think aloud '**reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{32}	*CP asks FCC how much ground time they should schedule for Msn #526 at New Orleans International Airport (unrequested information)*	FCC & DO try to control and respond to the multiple threads	FCC decides to schedule extra ground time to give the medical crew more time to load the patient. He tells CP to schedule 20 min.. ground time	FCC schedules time based on patient condition and patient load
t_{33}	MANAGE PATIENT Update Patient Status	Trigger	FCC asks DO if the patient will be traveling with an attendant. DO doesn't know so he calls the hospital to find out	FCC & DO jump from task to task often performing several tasks simultaneously
t_{33}	COMMIT PLAN Enter Plan in Computer MANAGE PATIENT Update Patient Status	Obtain Required & Seek Additional Information	FCC calls the emergency room to speak to the attending nurse	FCC explains that nurse to nurse communications is sometimes more effective than doctor to nurse (civilian doctors, in particular, are not accustomed to the military medical evacuation system where nurses run the show). Nurses may be more inclined to provide information that is pertinent to nurses
t_{34}			SL informs DO of ground transportation situation	FCC is still trouble shooting problems with AEC and inputting information into DMRIS

LEGEND

Italics - Incoming Information   Underline - Artifacts   UnSolicited Explanations   Solicited Explanations   ☆ Unsolicited **'think aloud** 'reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
			DO talks to patient's wife and apprises her of the situation	
t_{35}	<u>COMMIT PLAN</u> / <u>MAN. PATIENT</u> / <u>ARR. TRANS</u> Enter Plan Computer / Update Patient Status / Modify Mission: Patients Affected by Diversion	(Re-open) subtask -Modify Mission of Patients Affected by Diversion Trigger	CTL asks what to do with the patient they were supposed to drop off at Shaw AFB?	Confusion again about what to do with the patient they were scheduled to deliver to Shaw AFB (The stop was dropped from the plan at t_{27})
t_{36}			-FCC talks with attending nurse about the patient's status	FCC puts the call on speaker for all to hear
	ER charge nurse says PVC's are 1-2 per minute, tachycardia, heart rate 120. Patient should be on heart monitor. (requested information) Trigger	Cardiac Condition is Serious		- Nurse says PVC's are more frequent than AP stated. Status is worse than they thought
		- Dilemma/Confusion	- FCC relays information to DO	-DO & FCC concerned. Transport patient now for kidney problem or wait to manage cardiac condition? (Another opportunity to consult SG).

LEGEND

Italics - Incoming Information   <u>Underline</u> - Artifacts   UnSolicited Explanations   Solicited Explanations   Unsolicited **'think aloud '**reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{36}		- (Re-open) Subtask -Heart Monitor Requirement - Possible Plan Revision		 -
	COMMIT PLAN: Enter Plan Computer MAN. PATIENT: Heart Monitor Req't ARR. TRANS: Modify Mission: Patients Affected by Diversion			Multiple activities occurring simultaneously as individual members inside GPMRC try to work the various threads. There's a lot of cross talk and some confusion
t_{37}		Continue to work tasks that are close to closure	FCC asks DO about remain-over-night (RON) procedures for Keesler AFB	There appears to be a temporary change in RON procedures at Keesler which precludes have the patient RON there.
t_{38}		(2nd Apparent) CLOSURE Subtask - Modify Mission: Drop Last Stop	CP ask FCC to confirm that they will drop Shaw AFB	Apparently they hadn't received the last decision made at t_{27} or they were confused because of all the changes. Communication breakdown

LEGEND

Italics - Incoming Information Underline - Artifacts UnSolicited Explanations Solicited Explanations Unsolicited **'think aloud** 'reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{39}	COMMIT PLAN / MAN. PATIENT / ARR. TRANS. Enter Plan Computer / Heart Monitor Req't / Modify Mission: Patients Affected Diversion	Cope with multiple threads already underway		
			FCC asks for names and phone numbers of AP & RP to input into DMRIS	
		Another Distraction	FCC takes another call from an AEC	
t_{40}	MANAGE PATIENT Heart Monitor Requirement	All of GPMRC converge to solve this problem	DO tells DO about the PVC's/heart monitor situation	DILEMMA: AP says PVC's rare - don't need monitor, nurse says PVC's frequent - should have monitor
t_{41}		- Do we have the capability to adequately handle this patient?	FCC, DO, CTL, DO, SL discuss & look up the qualifications of the nurses on board Msn #526	- They discuss whether the nurses have ACLS experience (they do not), bring up fact that patient load on aircraft is light
		- Try to make this plan work		- Level of commitment to the plan is high. Nearly all tasks have been coordinated and are close to completion.

LEGEND

Italics - Incoming Information   Underline - Artifacts   UnSolicited Explanations   Solicited Explanations   ☆ Unsolicited **'think aloud '**reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{42}	MANAGE PATIENT Heart Monitor Requirement	Coordinate		MCD is responding to the on again, off again diversion to pick up the Urgent patient. At this point, the only communica-tion between the medical crews on Msn #526 and GPMRC was relayed via CP and the flight crew. The communica-tion breakdown at t_{36}, between GPMRC and CP rippled through the system and effected the coordination between CP and the flight crew , and the flight crew and the medical crew.
	MCD calls FCC to find out what's going on with the Urgent patient(*unrequested information*)	Trigger		
		Patch the plan	FCC explains the situation & apologizes for "jerking them around". Asks if anyone on board is comfortable with ACLS procedures	
t_{43}		Get MCD to accept the plan	FCC reviews patient information with MCD	
	- *MCD says she would prefer to have the monitor on and fax her all available patient information.*			MCD agrees to take patient.
	Trigger	CLOSURE MANAGE PATIENT - Update Patient Status - Heart Monitor Req't		Since the MCD is ultimately responsible for the patient, all plans are contingent on her acceptance

LEGEND

Italics - Incoming Information Underline - Artifacts UnSolicited Explanations Solicited Explanations ☆ Unsolicited **'think aloud '**reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{44}	COMMIT TO THE PLAN Enter Plan in Computer		FCC continues inputting information in DMRIS so he can fax the form to the MCD	☆ FCC "thinks aloud" imagining what information he would want/need if he were the MCD
t_{45}		CLOSURE COMMIT TO THE PLAN Subtask - Enter Plan in Computer	- DO attempts to fax form to MCD	DO has problem with fax, asks SL for assistance
	ARRANGE TRANSPORT Modify Mission: Patients Affected by Diversion	(Re-emergence) Subtask Modify Mission: Patients Affected by Diversion	- DO tells CTL to RON patient that was supposed to go to SHAW AFB at Wilford Hall. They will pick him up the day after tomorrow on the milkrun from Wilford Hall to Shaw	DO returns to this subtask after the fax is sent
t_{46}		CLOSURE Subtask - Modify Mission: Patients Affected by Diversion	- CTL calls Wilford Hall AEC to arrange RON - CTL calls Shaw AEC to inform him that they are dropping the stop and tells him about RON of scheduled incoming patient	All final details complete, Closure on all main tasks and their associated subtasks

LEGEND

Italics - Incoming Information Underline - Artifacts UnSolicited Explanations Solicited Explanations ☆ Unsolicited **'think aloud** 'reports

Case 1. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{47}	*NAS AEC calls in, thought Msn #526 was inbound in 10 minutes* *(unrequested information)*	Coordination	- DO updates NAS AEC on Msn 526 status	Another coordination issue. Ground transportation people in New Orleans were confused about when the plane was going to arrive. .
t_{48}		Have we missed anything?	FCC and DO review all data	
t_{49}		CLOSURE All tasks	Modification to plan complete	

LEGEND

Italics - Incoming Information Underline - Artifacts UnSolicited Explanations Solicited Explanations Unsolicited **'think aloud '**reports

Case 1. Continued

5.2.4 *Interesting Observations*

5.2.4.1 Intermingled Roles and Apparent Closures

One interesting aspect to note immediately was that the roles of the FCC and DO were very intermingled. Since the FCC was out of the room when the call came, the DO assumed the role of the FCC. When the FCC came back into the room and found the DO on the phone with the Urgent call, he began generating options to transport the patient, thus assuming some of the role of the DO. This may have contributed to some of the confusion associated with the "apparent closures" noted in the protocol. Apparent closures occurred when the participants believed they had satisfied the goals or subgoals, only to reopen them at a later time. In most cases, goals or subgoals were reopened as a result of new information coming in as the event progressed. However, on several occasions during this protocol, participants were distracted and lost track of issues, forcing previously closed goals and subgoals to be revisited. The intermingling of the roles and responsibilities of the primary participants may have contributed to the distractions and confusions as both the FCC and the DO tried to share and accomplish each others tasks outside of their principal operating domains.

5.2.4.2 Responsibility/Authority Issues

Another interesting occurrence during this protocol was the responsibility/authority double bind with respect to the Validation process. The Validation process requires medical knowledge, aerospace physiology

knowledge, knowledge of the rules and procedures in the AE system, and finally knowledge of how others use and abuse the system. Whenever there are doubts about the patient's condition and the appropriate methods to deal with those condition, the issue can be bumped up the chain of command for higher level consultation. It appeared that the FCC was unsure of his authority but hesitant to seek advice at a higher level. He eventually did confer with the flight surgeon after he had all of the pieces of the revised plan in place.

5.2.4.3 Information Comes in Over Time

An issue that significantly contributed to the number of apparent closures was the fact that information emerged over time. The DO and FCC immediately began to devise a plan based on the limited information obtained from the AEC. Later, new information from the AP prompted significant changes to the event-driven replanning approach. As the planning process continued to progress, new information about secondary disruptions prompted additional revisions to the planning approach.

5.2.4.4 Managing Multiple Threads

Members of the GPMRC spent a lot of time coordinating the activities required to transport the Urgent patient and manage those patients disrupted by diverting the aircraft. GPMRC members had to coordinate with several outside organizations to; arrange ground transportation at pick-up and drop-off points, get clearance to land at a civilian airfield, and accommodate the patient that was supposed to be dropped off at Shaw AFB. Team members managed these

various threads as they attended to the daily routine activities that continued to occur. These various pieces of the proposed plan had to come together in order to devise and enact the overall revised plan.

5.2.4.5 Conflicting Assessments and Goals

The primary events in this case centered on the conflicting assessment of the patient's secondary cardiac condition. Initially, the AP informed the DO that the patient was on a heart monitor. The DO went on to explain that aeromedical evacuation protocol requires a cardiac trained medical attendant accompany any patient on a heart monitor. As a result, satisfying the heart monitor requirement would delay picking up the patient by as much as four hours. Although both the FCC's and the AP's ultimate goal was to provide for the patient's welfare, they adopted different approaches to satisfy that goal. To the AP, taking care of the patient meant getting him to a more suitable treatment facility as soon as possible. To the FCC, taking care of the patient meant providing the required medical attendants and necessary equipment to provide suitable in-transit patient care. As such, their approaches were in conflict as the AP sought to move the patient out of his hospital while the FCC sought to keep the patient at the originating hospital until he could arrange the required equipment and medical attendants.

5.2.4.6 The Need for Negotiation

The AP quickly realized the need to negotiate in order to have the patient transported as soon as possible. He responded by down playing the significance

of the cardiac condition in relation to the patient's primary kidney condition. The AP eventually eliminated the requirement for the heart monitor thereby relaxing the constraint to provide a cardiac attendant. The AP was obviously frustrated as he tried to convey the insignificance of the patient's cardiac condition with respect to the immediate criticality of the patient's kidney condition. The FCC explained that the civilian AP's obvious frustration was probably caused by his unfamiliarity with the rules and operation of the military aeromedical evacuation system. A particular sticking point for many physicians is that nurses run the military aeromedical evacuation system. Sometimes it is difficult for physicians to acquiesce to the instructions of nurses. As such, physicians can sometimes appear uncooperative. Being aware of this potential difficulty, the FCC uses various methods to work around these difficulties when they arise. One method the FCC uses to obtain required information is to bump the issue up to the flight surgeon for a physician to physician consultation. The other method, which was used in this case, is to consult directly with the attending nurse. The FCC commented that nurses are more inclined to give fellow nurses the information they need to adequately perform their jobs.

The FCC called the originating MTF and asked to speak with the attending ER nurse to obtain additional information about the patient's cardiac condition. The attending nurse informed the FCC that the patient's cardiac condition was worse than what the AP had indicated. The attending nurse recommended having a heart monitor. The FCC had a dilemma on his hands.

His response to the dilemma was to apprise the MCD of the situation, and let her decide how to proceed.

5.2.4.7 Inaccurate Status Information

This case also provided an example of the potential ramifications of inaccurate information when status systems are not updated in a timely manner. Because the day shift controller had neglected to update the mission status board with regard to the patient load at Shaw AFB, the FCC and DO believed they had a transportation requirement there. As such, the FCC and DO tried to devise a revised plan that would accommodate the Urgent patient and satisfy the secondary constraint of transporting the Special patient at Shaw AFB. This error prompted consideration of a constraint that was not pertinent in this situation. This precipitated several apparent closures as the GPMRC crew gradually determined the true status of the patient requirements at Shaw AFB over time.

5.2.5 Results of an Expert Review of the Protocol

This case was later reviewed and critiqued by an expert FCC with more than nine years aeromedical evacuation experience. He had worked as an FCC in Desert Storm and had spent several years in Europe and the Middle East. The expert concurred with the FCC's and the DO's initial strategy to send a separate aircraft and avoid disrupting the plan in progress. He pointed out that although this is the easiest solution, it also usually the most costly. However, the expert could not understand why the participants in Case 1 started arranging

transportation right away. He stated that the first order of business should always be to obtain as much information as possible on the patient's condition. The expert was amazed to see that the participants did not obtain information on the patient's status until they were well into the replanning process. This prompted the expert to inquire about the experience levels of the FCC and the DO. He went on to explain why the participants on duty during this episode might have jumped the gun and starting arranging transport before they had a clear picture of the patient's condition. He noted that practitioners who have not worked in crisis situations (i.e. Grenada, Operation Dessert Storm, Bosnia peacekeeping missions) tend to get very excited and overreact when an urgent situation arises. Novices in these situations tend to think they have to do everything "right away". They don't stop to think that the extra 5-10 minutes it might take to obtain additional information won't jeopardize the situation and will probably save them much more time in the long run. The expert went on to say that it is up to the FCC to take charge and orchestrate the replanning process. Personality or experience level might explain why the FCC on duty that evening did not efficiently control the replanning activity. Had there been more central control and appointed responsibilities, they may not have experienced as much difficulty reaching closure on secondary disruptions.

5.3 Case 2: Urgent Patient Outside CONUS

5.3.1 The Context

The day shift was barely underway when the call came into the GPMRC at approximately 0730 CST on a Wednesday morning. The DO had been on duty for an hour and the rest of the GPMRC crew including the FCC had been on duty for approximately thirty minutes.

5.3.2 The Urgent Call

The patient was an Air Force active duty reserve officer in his early forties. He was participating in a training exercise in Haiti when he began experiencing chest pain. The patient's cardiac enzymes were elevated and the cardiac monitor showed sinus rhythm at a rate of 40-60 beats per minute and minimal PVC's. The AP at the field hospital started a lydocaine drip. The field hospital was a minimal care treatment facility and was unable to provide treatment beyond what they were currently doing. They did not possess the equipment to conduct further tests to determine the nature of the patient's cardiac problems. The AP knew the patient needed care beyond the capability of the field hospital in Haiti but he did not have a suitable destination MTF or receiving physician set up or in mind when he placed the call to the GPMRC. The locations of all of the participants involved in this case are displayed in Figure 5.

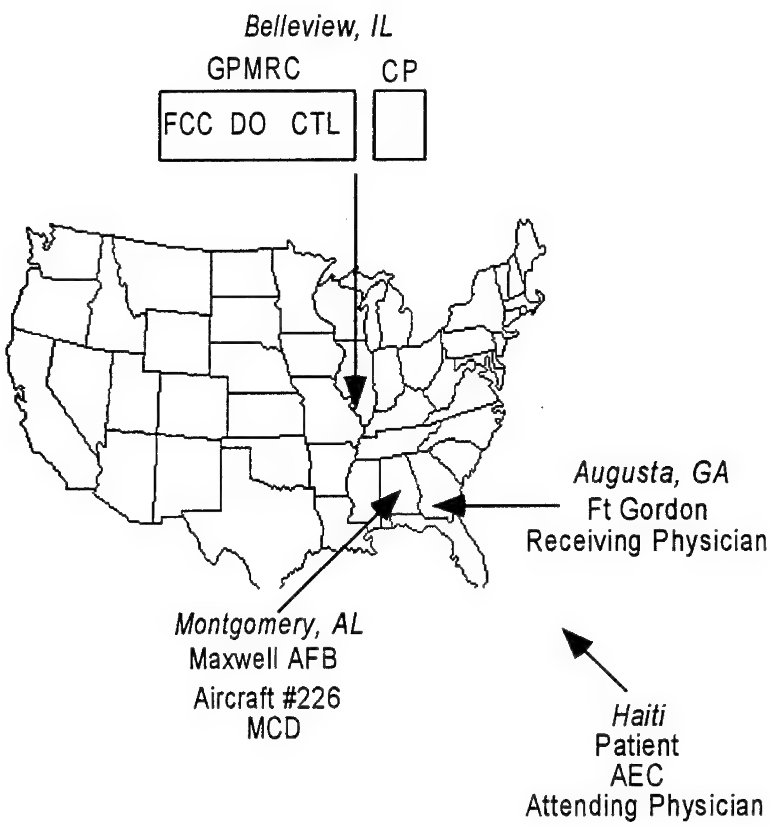


Figure 5. Location of Participants in Case 2. The patient was located at a field hospital in Haiti. The destination medical treatment facility was Ft Gordon hospital in San Augusta, GA. The MCD was enroute to Maxwell AFB on Aircraft #226.

5.3.3 Protocol for Case 2 (presented on the following pages)

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_0	*AP in Haiti calls in Urgent PMR (unrequested information)*	Trigger →	FCC takes call	
t_1	VERIFICATION	Is this truly Urgent?	FCC seeks information on patient's status	FCC writes information down on a sheet of paper
	EKG: elevated tachycardia on 2mg/min lydocaine drip. No cath. capability (requested information)			FCC talks about doing triage in her head
t_2		CLOSURE VERIFICATION	FCC decides patient is urgent	FCC explains that Haiti is only a field hospital with minimal capability
t_3	ARRANGE TRANSPORT	Generate options (Back-up)	DO looks at <u>Status Board</u> for potential planes to divert	DO anticipates possible divert situation if other options don't pan out
	AP states that he does not have a RP Trigger →	Find destination MTF		
t_4	ARRANGE TRANSPORT / MANAGE PATIENT			FCC and DO work on different tasks
	DO: Search for opportune Aircraft / FCC: Find Destination MTF	-1st option: Call TACC- Haiti is out-side CONUS	DO calls TACC- asks if there are any opportune aircraft in that area	TACC handles overseas missions

LEGEND

Italics - Incoming Information   <u>Underline</u> - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 2. Urgent Patient at a Civilian Hospital

Time	Event/Task		Mindset	Activity Inside GPMRC	Commentary
t_5	ARRANGE TRANSPORT DO: Search for opportune Aircraft	MANAGE PATIENT FCC: Find Destination MTF			
	TACC says no aircraft in that area (requested information) → **Trigger**		-2nd option: Check with Training Squadrons	DO asks TACC to call training squadrons to see if any would be in the area	Training squadrons relish opportunities to transport "live" patients. Drawback- aircraft/ equipment may be limited or outdated.
				DO waiting for TACC to call back	DO comments that he would like direct access to the training squadrons.
t_6			-3rd option: Hire Civilian Air Ambulance		DO considers Civilian Air Ambulance, but knew from previous experience and calculations that it would be too expensive
			Keep divert option open		DO explains a "little rule" that C-9's can't be in Haiti after dark. DO looks for planes in the Southwest going east. There were two options: Msn #226 and #221

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 2. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_6	ARRANGE TRANSPORT; MANAGE PATIENT			
	DO: Search for Opportune Aircraft; FCC: Find Destination MTF	Find place to land	DO pulls out book and sees only place to land in Haiti is Port-au-Prince Int'l Airport. He informs CP	
t_7	DO: Determine Where to Land	CLOSURE: Sub-task - Determine Where to Land		
t_4	DO: Search for Opportune Aircraft; FCC: Find Destination MTF	Find closest MTF with the capability to handle cardiac	FCC inputs information into DMRIS so the computer can find the hospital with the closest capability	
t_5	*DMRIS comes back with Walter Reed Hospital as closest capable facility*	DMRIS answer is no good		Walter Reed is in Washington DC . FCC wanted a facility closer to Haiti
t_6		Trigger	FCC calls Ft Gordon AEC and asks to speak to someone in cardiology	FCC says she's going to "stretch her neck" to find a doctor who would accept the patient. She knows Ft Gordon is closer and has the capability

LEGEND

Italics - Incoming Information Underline - Artifacts Unsolicited Explanations Solicited Explanations

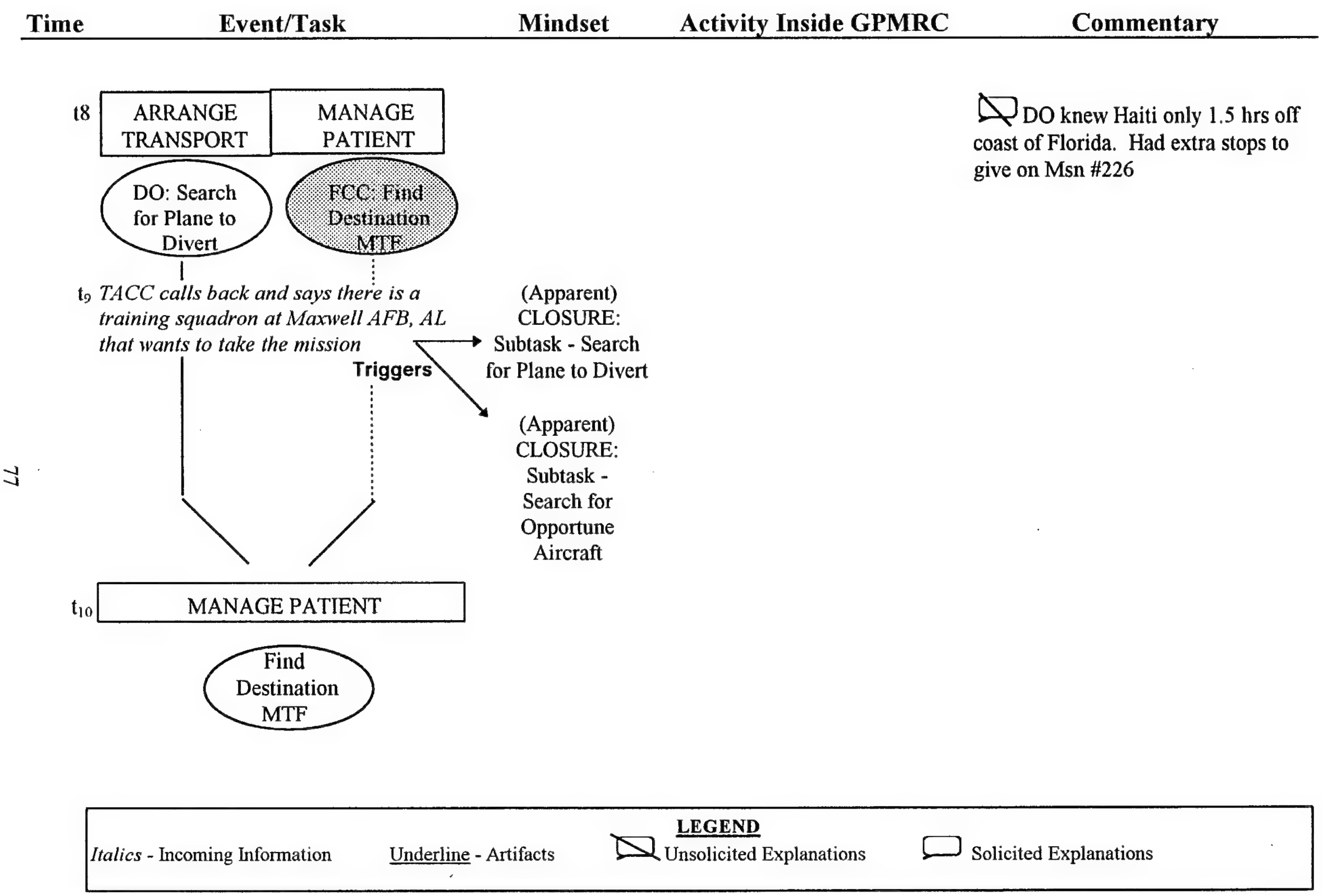
Case 2. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
	ARRANGE TRANSPORT: DO: Search for Opportune Aircraft; MANAGE PATIENT: FCC: Find Destination MTF			
t_7	*Cardiology doctor at Ft Gordon gets on the phone*		FCC explains situation and provides patient status to doctor	
	Dr. at Ft Gordon doesn't think the situation is urgent	This is an urgent situation	FCC explains limited capability of MTF in Haiti to handle the situation.	Possible indication that FCC believed doctor-to-doctor communication would be more effective
			FCC asks doctor at Ft Gordon to speak with AP in Haiti	
t_8	DO: Search for Plane to Divert; FCC: Find Destination MTF		DO still waiting for a call from TACC	
		Keep divert option open	DO looks at Msn #221 #226. Rules out #221, looks at patient load	Msn #221 had too many stops, it would run out of crew duty day

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 2. Continued



Case 2. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{10}	MANAGE PATIENT			
	Find Destination MTF			
	Doctor at Ft Gordon says he will accept the patient → Trigger	CLOSURE: Subtask- Find Destination MTF		
t_{11}	Patient Requirements	FCC shifts to next subtask	FCC tells DO the aircraft must have heart monitor, IV, O_2, and ACLS equipment	
t_{12}	*Maxwell AFB training squadron calls in for additional information (unrequested)*		FCC and DO tell training squadron patient status and transportation requirements	Training squadron would like to do the mission if possible
t_{13}		Training Squadron will transport patient	FCC tells AP he must provide ACLS qualified attendant	Protocol states that originating MTF must supply medical attendants

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 2. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{14}	MANAGE PATIENT Patient Requirements			
	AP says can't spare personnel → Trigger	New Subtask - Find Medical Attendant		FCC commented that she knew field hospitals were very understaffed. She would help them out by finding an attendant
t_{15}	Find Medical Attendant			
t_{16}		FCC- Explore other options DO- Make this plan work	FCC tells DO to look at #226 again	DO hesitant- let the training squadron handle it. Don't disrupt the plan in motion

LEGEND

Italics - Incoming Information · <u>Underline</u> - Artifacts · Unsolicited Explanations · Solicited Explanations

Case 2. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{17}	ARRANGE TRANSPORT			
	Search for Plane to Divert	(Reopen) Subtask- Search for Plane to Divert	DO asks CP if #226 has over water equipment	Aircraft going over water for any period of time must have over water equipment
	CP reports that #226 does have over water equipment on board			
t_{18}	*Maxwell calls back again to talk to FCC and DO (unrequested information)*			Maxwell has questions about the proposed mission
t_{19}			FCC and DO go back and forth with Maxwell training squadron	- FCC and DO hang up. They both continue to work other issues - 20 or 30 minutes pass
t_{20}	*Maxwell calls back and says they can't support the mission (unrequested information)*	(Re-open) Subtask - Search for Plane to Divert		Training squadron had a mission scheduled the following morning. Flying to Haiti would interfere with crew rest for the following day's mission

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 2. Continued

Time	Event/Task		Mindset	Activity Inside GPMRC	Commentary
t_{21}	ARRANGE TRANSPORT	MANAGE PATIENT			
	DO: Search for Plane to Divert	FCC: Find Destination MTF		DO looks at patients onboard Msn #226; sees only one patient to drop off at Birmingham	Msn -#226 was on its way to Maxwell AFB. Original plan was to go from Maxwell to Birmingham to Eglin to Columbia then back to Scott
			Divert Msn #226		-Patient going to Birmingham was a retiree returning from a routine visit for kidney stones. He was ambulatory, and in good condition
			CLOSURE: Search for Plane to Divert		
t_{22}	Modify Mission: Drop Stop		Buy more crew duty time	Do decides to drop the Birmingham stop. DO calls AEC to have him inform the patient's family that they will have to pick him up at Maxwell (approximately 3 hours from Birmingham)	DO knew AEC in Birmingham. Said he owed him a favor

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 2. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{23}	*Birmingham AEC says they would send a car to pick up the patient*	CLOSURE (Sub-task) Modify Mission: Drop Stop		
t_{24}	ARRANGE TRANSPORT / MANAGE PATIENT DO: Modify Mission / FCC: Find Medical Attendant	Make this work	- DO walks to the Planning Map to "string" a revised mission - DO strings Maxwell to Eglin to Haiti to Ft Gordon to Columbia to Scott - CP starts coordinating this tentative revised mission	DO considers taking on fuel for the outbound to Haiti.(That's why he opts to go to Eglin before Haiti) Need diplomatic clearance to land in Haiti
t_{25}		(Apparent) CLOSURE: Modify Mission		
t_{21}	DO: Modify Mission / FCC: Find Medical Attendant		FCC told CTRL for #226 to call AEC at Maxwell and have the MCD call back to GPMRC	-FCC wants to let MCD know what's going on as soon as possible -CTRL tells FCC names of medical crew on #226. A flight nurse was on board giving a check ride who FCC knew was ACLS instructor and experienced in cardiology (What Luck!)

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 2. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
	ARRANGE TRANSPORT / MANAGE PATIENT			
t_{21}	DO: Modify Mission; FCC: Find Medical Attendant			
t_{22}			-FCC calls chief nurse as courtesy to let her know that the check ride nurse will be used as an attendant	
t_{23}			-FCC calls AP in Haiti and tells him she has found a medical atten- dant	
t_{24}			-FCC calls Ft Gordon AEC and tells him to arrange for an ACLS qualified nurse or a doctor meet the plane	FCC explains that patient must have continuous care She knew that the aircrew could not afford the ground time required for the check ride nurse to accompany the patient to the hospital and then get back to the aircraft. They would bust crew duty limit

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 2. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{25}	*Ft Gordon AEC says no problem; will have ACLS nurse or doctor meet the plane*	CLOSURE: Find Medical Attendant		
t_{26}	ADMINISTRATION	Manage Loose Threads		
			FCC looks at records of patients on #226. There is a "special" (Do Not Resuscitate (DNR)) patient on board	DNR patient has terminal cancer
t_{27}	*MCD calls in to talk to FCC*		FCC explains revised schedule to MCD. Asks about the special	
t_{28}	*MCD says she is not comfortable with taking the DNR patient to Haiti*			DNR patient not in good shape. MCD was leery of putting her on the plane in the first place. Also, if a patient dies enroute, rules state that the body must be off-loaded at the next stop. If the patient died, they would have to leave her in Haiti

LEGEND

Italics - Incoming Information Underline - Artifacts Unsolicited Explanations Solicited Explanations

Case 2. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{29}	*MCD asks if mission can be rerouted (unrequested information)*	FCC - (Reopen) Sub-task- Modify Mission	FCC argues on behalf of the MCD to have the mission rerouted. Wants to drop off special patient before going to Haiti	
t_{30}	ADMINISTRATION	DO and CP - CLOSURE: Modify Mission	DO and CP argue the work and coordination required to arrange the current revised plan	DO tell the FCC she's "pushing it"
t_{31}		DILEMMA: FCC/MCD and FCC/CP go back and forth on this issue		DO argues that rerouting would break crew duty limits
t_{32}	*MCD recommends changing the mission profile* →	(Reopen) Subtask- Modify Mission		
t_{33}	ARRANGE TRANSPORT Modify Mission		DO restrings mission to go from Maxwell to Columbia to Haiti to Ft Gordon to Eglin to Scott	DO says this works out better because it is easier to clear customs at Eglin
t_{34}			CP starts working it	CP not happy at all

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 2. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{35}	COMMIT PLAN			
	Enter Plan into Computer	CLOSURE: All tasks		

LEGEND

Italics - Incoming Information — Underline - Artifacts — Unsolicited Explanations — Solicited Explanations

Case 2. Continued

5.3.4 *Interesting Observations*

5.3.4.1 Patient Located Outside the CONUS

This case had many interesting twists. First, the originating MTF was in Haiti. Typically, the aircraft and aircrew located at GPMRC are only responsible for transporting patients *within* their theater of operation (i.e. the continental United States). The TACC, on the other hand, is responsible for transporting patients *between* theaters of operation. Consequently, when the Urgent call came in, the DO immediately contacted the TACC. When the DO learned that the TACC did not have any aircraft available in the vicinity, he asked them to contact training squadrons that would be able to respond in a timely manner. TACC did find a training squadron that wanted to take the mission. In the end however, the training squadron could not support the mission. What was also interesting here was that when the DO handed off the coordination of transport to TACC, there was a lot of "dead time" as GPMRC crew members waited for updates from the TACC. In fact, it took over two hours to implement a revised plan to deal with the disrupting Urgent call in this case. There were three prominent time lags that contributed to the long planning process. First, there was dead time while the DO waited for the TACC to determine their ability to support the mission. Then there was a substantial time lag while the TACC was trying to locate a training squadron that might be able to support the mission. Finally, there was another significant time lag while the training squadron considered their ability to support the mission. During these time lags however,

the DO did lightly consider his options in the event that the GPMRC had to provide the transport. The DO knew that Haiti was just a couple of hours off the coast of Florida. He also knew from previous experience that hiring a Civil Air Ambulance would be too costly. Flying a smaller C-21 aircraft was never an option because they are not equipped to fly over water.

5.3.4.2 Arrange Destination MTF

Another unique aspect of this case was the fact that the FCC had to find a destination MTF and a RP. The FCC wanted to transport the patient to the closest hospital with the capability to care for the patient. When the FCC input the patient's data into the DMRIS to locate a hospital with the closest capability, it came back with Walter Reed hospital which is just outside of Washington, DC This was unacceptable to the FCC because she knew there were hospitals closer to Haiti that could provide the care that the patient needed. She knew Ft Gordon had a cardiac facility that could perform the appropriate tests to determine the patient's condition.

5.3.4.3 Compelling Secondary Disruption

Perhaps the most engaging aspect of this case was that a secondary disruption shaped the replanning process as much as the primary disrupting event. The initial revised plan was structured around picking up and delivering the Urgent patient in the most expeditious manner. The diverted aircraft was to proceed to Haiti, pick up the Urgent patient, transport the patient to Ft Gordon, and then resume the previous mission itinerary. When the FCC informed the

MCD of the proposed plan, the MCD objected based on the deteriorating status of a patient on the aircraft. The FCC did know that there was a Special, do not resuscitate (DNR) patient onboard, but she did not know that the patient's condition had deteriorated, otherwise she would have factored that information into the replanning process. The MCD explained that she was reluctant to take the patient in the first place and she wasn't sure the patient would make the trip to Haiti and back. The FCC and the MCD discussed the consequences of the DNR patient arresting and dying enroute to Haiti. If this happened, regulation required that the medical crew on board the aircraft off-load the body at the next stop. They did not want to risk having to leave the patient's body in Haiti. In the end, the FCC convinced the DO and CP to revise the proposed plan to drop the DNR patient off before going to Haiti.

5.3.4.4 Apparent Closures

Several apparent closures occurred during the event-driven replanning process for this case. Most of the apparent closures were the result of new information coming into the GPMRC. When the TACC reported that they found a training squadron that wanted to take the mission, GPMRC members believed they had a mode of transportation so they were no longer looking for opportune aircraft or planes to divert. When the training squadron came back later and declined the mission, GPMRC crew members had to reinitiate their search for a mode of transportation.

The second apparent closure occurred when the DO and CP devised a proposed plan to transport the Urgent patient based on the information at hand. When the MCD heard the proposed plan, she provided additional information that prompted the DO and CP to modify the itinerary of the proposed plan. Unfortunately, by the time the divert aircraft landed at Maxwell AFB and the MCD was instructed to call back to the GPMRC, the proposed plan was already established.

The third apparent closure occurred when the FCC found a medical attendant to care for the patient during flight. Later she realized that the medical attendant would not be able to accompany the patient to the hospital because of crew duty day considerations. As a result, she had to arrange to have a medical attendant meet the aircraft to provide continuous patient care from the aircraft to the medical treatment facility.

5.3.4.5 Looking Ahead

Members of the GPMRC continually looked ahead to anticipate potential problems and actions that might arise in the future. For instance, when the DO began planning to divert Flight #226, he projected that the crew would have to take on extra fuel before flying to Haiti. He also considered that the plane would have to clear customs when it returned from Haiti, so he wanted to bring the plan back into an airfield that would allow them to clear customs easily.

5.3.4.6 Planning Strategies

This case highlights several different planning strategies. The FCC utilized an opportunistic strategy when she looked at the qualifications of the medical crew and found a Standard-Evaluation officer, who was on board administering a check-ride, was ACLS qualified. The DO displayed a case-based planning strategy when he was able to immediately rule out hiring a Civilian Air Ambulance based on a previous experience similar to the situation at hand. In addition, this case highlights the drawbacks of employing a strictly depth-first approach to the event-driven replanning process and the disadvantages of having to proceed with the planning process when information is incomplete. Employing a depth first and abstraction hierarchy approach proved costly when planners realized that the "details" (i.e., secondary disruptions) were as critical as the primary problem.

5.4 Case 3: Equipment Problems

5.4.1 The Context

It was a calm Thursday morning, approximately 1030 CST. The crew at GPMRC had been on duty for several hours. The FCC was reviewing the medical and equipment requirements of ongoing missions. The DO was monitoring the progress of ongoing missions.

5.4.2 The Situation

While reviewing the equipment requirements for ongoing missions, the FCC noticed that a patient with seizures and a temporary pacemaker was scheduled to fly on a C-21 later that morning. Realizing an external pacemaker's potential for causing electro-magnetic interference (EMI) on the aircraft, the FCC called the AP at the originating MTF. The AP explained that it was an internal pacemaker and hence would not pose a problem. The AP then went on to ask if he could substitute a Pack 9 (style/model of cardiac monitor) for a Pack 8 because he was unable to locate a Pack 8 anywhere in the Colorado Springs area. The FCC told the AP that neither Pack was authorized on a C-21 aircraft. The AP angrily relayed that his people had spent the entire morning trying to locate the Pack 8 which had been approved by someone at GPMRC. An error had been made. The AP informed the FCC that the patient was to be transported in approximately 2 hours. The FCC set out to find what type of monitor would be acceptable on a C-21.

5.4.3 Protocol for Case 3 (presented on the following pages)

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_0	ADMINISTRATION	<u>Trigger</u> →	FCC calls AP at AFA to check on pacemaker	FCC called to see if Patient had external pacemaker. It could cause EMI on C-21
		Potential Problem		
t_1	*AEC says is an internal pacemaker, so poses no problem. However, can substitute Equipment Pack 9 in place of Pack 8?* *(requested unrequested information)*	New Real Problem Arises	FCC recognized there could be a problem with the equipment. Informs AP that neither Pack 8 or Pack 9 is approved on C-21 - Asks what else they have available	AEC says had called all over Colorado Springs area, could not find a Pack 8
t_2	VERIFICATION			
	Equipment manager at Brooks AFB in San Antonio calls back and verifies that Packs 8 and 9 are unacceptable *(requested information)*	How did equipment get authorized?	FCC calls unit in San Antonio responsible for approving equipment on all airframes	FCC wants to make sure they get the right equipment on plane
t_2	*Equipment Manager will not waive* *(requested information)*	Can waive?	FCC takes out equipment book and begins going through it with Equipment Manager at Brooks	
		Find Acceptable Alternative	FCC gives DO heads up	

LEGEND

Italics - Incoming Information <u>Underline</u> - Artifacts Unsolicited Explanations Solicited Explanations

Case 3. Equipment Problems

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_3	ARRANGE TRANSPORT Search for Plane to Divert		FCC calls AP and tells him to find acceptable equipment. AP says already contacted everyone in area. FCC gives AP phone number of Equipment Manager to speak directly with him	AFA upset.
t_3			DO looks at <u>Status Board</u>, says could possibly divert Msn #666 to pick up Patient, but would not be able to transport to destination MTF until following day.	
t_4		Potential Error	FCC looks over paperwork; wants to know who or why this was originally approved	
t_5		Correct Mistake - Could be reperc-ussions	FCC calls SG to apprise of situation and seek advise	Crew at Peterson AFB alerted to support his mission.

LEGEND

Italics - Incoming Information   <u>Underline</u> - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 3. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_5	ARRANGE TRANSPORT			
	DO: Search for Plane to Divert			
	SG asks what are options?	→ Trigger	FCC generates options: a) see if AP will waive monitor requirement b) divert Msn #666, find out if AP will accept Patient RON at Scott AFB and delivery to Wilford Hall following day c) call critical care team out of San Antonio to see if they could go fly out and transport patient	Don't think FCC explicitly thought of options until he was asked by SG
t_6			DO goes to lunch, 2nd DO fills in	

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 3. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_7	ARRANGE TRANSPORT Search for Plane to Divert	Inform chain of command of incident	FCC tells chief o GPMRC what's going on. Tells her options. She amends option a) to see if AP will accept turning the monitor off during take off and landing	
		Requires Flt Crew approval		
t_8	MANAGE PATIENT		FCC goes to lunch - Replacement takes over.	
		Cover <u>all</u> bases. Have several options on standby	Call ASTF, give heads up. Find a potential RP and see f they can handle a pacemaker patient RON	
t_9	ARRANGE TRANSPORT Search for Plane to Divert	Establish/ maintain good relationship with anyone who may be in a position to help	Call Colonel in charge of Critical Care Team in San Antonio, gives heads up about potential pick-up in Colorado Springs	FCC knows they won't turn it down. The Critical Care Unit is always looking for opportunities to train and justify their existence. Besides, they "owe me one" she says.

LEGEND

Italics - Incoming Information   <u>Underline</u> - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 3. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{10}	MANAGE PATIENT		Call AP, give him 3 options. Acting FCC emphasizes Option 2. Stresses that C-9 is much more equipped to handle the patient. She tells AP she will have a RP at RON site call to ensure continuity of care for patient	Negotiation FCC is jumping back and forth between threads
			AP opts for option 2. FCC tells acting DO to divert Msn #666 into Colorado Springs	
t_{11}	ARRANGE TRANSPORT Modify Mission Drop Last Stop ← Trigger	Pushing crew duty day limits	Acting DO says he will delay making the call until the plane gets to Colorado Springs. Looks at schedule to see who picking up/dropping off at last stop (Whiteman AFB)	Plane was running ahead of schedule - might be able to divert and make the last stop

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 3. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{12}	ARRANGE TRANSPORT Modify Mission-Drop Last Stop		DO gives word to cancel the C-21 out of Peterson AFB	Everyone at GPMRC is pretty upset about this. The guys from Peterson were doing GPMRC a favor by moving the patient, now they are pulling the rug out from under them moments before takeoff. Afraid they "cried wolf" and they might not be willing to help out in the future.
t_{13}	MANAGE PATIENT			
	ASTF calls back. She has found a Dr. that agreed to accept patient to RON (requested information)		FCC tells ASTF to have RP call AP, then confirm back after they have spoken	Acting FCC wants to make sure everyone is on the same page
			FCC faxes patients <u>Form 5</u> to ASTF and asks her to forward to RP	
		Manage loose threads	FCC calls SG, lets him know what's going on	
t_{14}	*SG calls back to find out if AP is upset*	Distraction		

LEGEND

Italics - Incoming Information Underline - Artifacts Unsolicited Explanations Solicited Explanations

Case 3. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{15}	MANAGE PATIENT		FCC calls Critical Care Team in San Antonio, tells them won't be needing them, but thanks them	
t_{16}	*CP stick head in door and says C-9 will be too heavy to take off out of Colorado Springs* Trigger	CLOSURE: MANAGE PATIENT	DO returns from lunch	Aircraft is scheduled to refuel at the stop prior Offut AFB to Colorado Springs. When temp is high (90s), they can't get enough lift at airport altitude.
t_{17}	ARRANGE TRANSPORT	Problem: Generate Options	CP, DO and acting FCC discuss options: a) don't refuel at Offut and drop last stop b) DO says, take on a little fuel at Offut, go to Colorado Springs, then make last stop - refuel at Whiteman AFB to make trip back home	
	CP says extra refueling would require increasing ground time which could bust crew duty day	Make this work	CP and DO decide to try to "massage" the numbers to get the computer to accept it	

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 3. Continued

Time	Event/Task	Mindset	Activity Inside GPMRC	Commentary
t_{18}	ARRANGE TRANSPORT			
	CP yells that it worked		SL calls AE at Offut to tell medical crew to call back to Scott	Let medical crew know plan changes
			CP calls CP at Offut to have flight crew call back to Scott	Let flight crew know plan change
t_{19}	*MCD calls in to find out what's going on*		FCC relays all information on Form 5, informs her of situation	
		CLOSURE ARRANGE TRANSPORT		

LEGEND

Italics - Incoming Information   Underline - Artifacts   Unsolicited Explanations   Solicited Explanations

Case 3. Continued

5.4.4 Interesting Observations

5.4.4.1 An Error was Made

In this case, the unanticipated event resulted from an error made by someone in the GPMRC. The FCC from the previous shift had mistakenly cleared the use of unauthorized equipment on the C-21. It is unclear whether the FCC failed to read or misread the guidelines on acceptable equipment that are located in a binder on a shelf directly behind the FCC's desk. Another explanation might be that the FCC mistakenly believed she had the authority to clear equipment onboard aircraft. Luckily the problem was caught prior to the scheduled transport.

The FCC immediately informed the commander of the GPMRC and the SG to make them aware of the problem. Since the GPMRC caused this unanticipated event, the entire chain of command was anxious to resolve the situation as quickly as possible. An additional complicating factor was that the aircraft scheduled to transport the patient was not owned by GPMRC. The FCC from the previous shift had arranged the transport with a unit out of Peterson AFB, CO. As such, the chain of command at the GPMRC was very concerned about tarnishing their reputation. They were worried about future interactions with physicians at the Air Force Academy and future support from the unit out of Peterson. A senior FCC was called into the control room to oversee the event-driven replanning process. The senior FCC took control of the situation when the FCC on duty went to lunch.

5.4.4.2 Negotiation

Negotiation played a key role in the resolution of this event-driven replanning process. The FCC's who worked this case were very much aware of the fact that they had to come up with a solution that the AP would find acceptable. They knew that the AP's feathers were ruffled and they would have to appease him. The FCC quickly began to generate options to resolve this problem. They determined what they considered to be the best course of action and subsequently went on to convince the AP of the same.

5.4.4.3. Managing Multiple Threads

The senior FCC who took over when the FCC on duty went to lunch was extremely adept at handling multiple threads of activity. She assigned tasks and orchestrated the coordination required to have several plans in place at one time. She demanded timely updates on the tasks that she assigned and provided continuos feedback to everyone involved in the planning process.

5.4.4.4 Planning Strategies

The planning approach taken in this case was primarily breadth first. The FCC, with the help of the GPMRC commander and the SG, generated three options:

1)See if AP will waive the monitor requirement during critical phases of flight. (This would also require getting the C-21 flight crew to accept having the monitoring on during non-critical phases of flight)

2)Divert Flight #666, and see if AP will accept the patient staying over night at Scott AFB with delivery to the destination MTF the following day

3)Call the Critical Care Team in San Antonio and see if they can support the mission.

The FCC coordinated all three options. She had the Critical Care team in San Antonio on standby, she had coordinated the accommodations for the patient's stay at Scott AFB, and had the staff at the ASTF on standby to receive the patient. Once the AP agreed to one of the options, the GPMRC team would be ready to initiate the revised plan.

Recognition/Case based planning was also evident when the DO recalled a previous experience to explain how to split the refueling stops to avoid being too "heavy" to takeoff out of Colorado Springs.

Another interesting thing to note about this case was that of the three options generated, the members of the GPMRC preferred the option that **would** disrupt the plan in motion. This is contrary to planners' normal option selection. Perhaps it was because they felt responsible for the unanticipated event, and hence felt the need to take care of the problem themselves.

5.4.4.5 Relaxing Constraints

Relaxing constraints played significant roles in the event-driven replanning process of this case. Two of the options that the FCC presented to the AP involved constraint relaxation. The first option called for relaxing the constraint for the cardiac monitor. The second option relaxed the constraint to deliver the patient to the destination MTF that day.

CHAPTER 6

DISCUSSION

6.1 Introduction

Interesting themes emerged while developing and analyzing the protocols from the three cases presented in this research. The analysis revealed several fascinating and unexpected findings that could have major implications for the design of systems to support the event-driven replanning process

First, planners used multiple strategies to develop and refine plans in response to emerging constraints. Constraint identification and management drove the event-driven replanning process. Event-driven replanning is, by nature, situated planning, but the results of this research revealed that planners also employed opportunistic, case-based, and hierarchical planning strategies during the replanning process. Event-driven replanning, as observed in the aeromedical evacuation domain, utilized aspects of case based planning whereby planners did not replan from scratch, rather, they utilize portions of plans encoded in memory that possessed characteristics that were similar to the situation at hand. Planners relied on recognition and case-based strategies to

assess situations and select courses of action. In addition, planners used primarily a depth first approach to replan activities to accommodate the disrupting event. Planners latched onto the first option that showed promise of handling the disrupting event, disregarding the potential ramifications that would ensue as a result of reallocating committed resources.

The **second** significant finding uncovered during this research was that information coming in over time and multiple threads created apparent closures that forced planners to reopen and revisit tasks that had been previously closed or dealt with. Information coming in over time compounds the complexity of event-driven replanning because it affects many aspects of the replanning process. New information coming in over time was the primary cause of apparent closures in the event-driven replanning process. As new information comes in, it must be folded into the event-driven replanning process. Very often however, this new information changes the status of tasks by changing the priority of constraints. Consequently, tasks that were previously completed or close to completion may have to be reopened or redirected based on the constraints and demands revealed by new information. Information coming in over time continually changes the nature of constraints the planners faced. As a result, planners do not have the luxury of a standard set of constraints on which to devise workable solutions to disrupting events in the early stages of the replanning process.

The second cause of apparent closures was multiple threads that went on in parallel. Event-driven replanning is a complex process that requires coordinating, tracking, and managing multiple tasks, subtasks, issues and related activities. Adding to this complexity is the fact that the data and the knowledge required to perform these tasks, issues, and activities resides with different individuals who are either functionally or spatially distributed. Adding still more layers of complexity, are the facts that individuals may handle multiple tasks issues and activities **and** these tasks, issues and activities can be distributed across multiple individuals. When multiple people are handling multiple tasks to achieve one goal, it is not surprising that sometimes tasks are dropped, disappear, and reemerge resulting in apparent closures.

The **third** significant finding was that planners relied on negotiation as a means to deal with constraints. Constraint identification and relaxation are critical aspects of the event-driven replanning process. Planners must identify constraints that may obstruct the current planning path and limit their ability to complete the plan. Once constraints are identified, planners attempt to relax the constraints via negotiation with the party responsible for that constraint. Hence, negotiation is, by nature, a cooperative process. Constraints arose as a new information came in over time. As new information came in, planners were required to identify the associated constraints and then determine how to manage those constraints. Planners relied on their knowledge of the procedures, operations, and rules of aeromedical evacuation to assist in the constraint

identification process. During the constraint management process however, planners relied primarily on their experiences and their ability to negotiate.

The **fourth**, and most surprising finding was the unexpected discovery that planners did not explicitly consider the impact of secondary disruptions when they revised plans to accommodate unanticipated disrupting events. When an unanticipated event occurs, the planners implicit goals are to: 1) accommodate the primary disrupting event, 2) accommodate the resultant secondary disruptions, and 3) minimize the workload on the GPMRC crew members. What is surprising is that the approach taken by planners does not incorporate two out of three of these goals. It appeared that accommodating an Urgent patient dominated other factors including the workload needed to manage secondary disruptions and the cost of change to the less critical patients. This absolute priority of Urgent patients over other factors may make aeromedical evacuation replanning different from other forms of event-driven replanning. Given the costs associated with changing plans in progress, it was hypothesized that planners would actively seek solutions that minimized secondary disruptions. Instead, planners approached the replanning process with the mindset of accommodating the disrupting event as quickly as possible without considering the potential secondary disruptions and resultant workload that might ensue. Planners pursued the first solution that feasibly handled the primary disrupting event and opted to manage the secondary disruptions that followed.

6.2 Event-Driven Replanning Strategies

In the realm of planning, numerous researchers have attempted to model the planning process. Models of planning posit that planning is; case based (Hammond, 1979), opportunistic (Hayes-Roth & Hayes-Roth, 1979), situated (Suchman, 1991) or hierarchical (Sarcedoti, 1979; Hoc, 1988; Xiao, 1994). Observations made during this research revealed that people do in fact use components of **all** of these approaches along with other techniques during the event-driven replanning process.

The first strategy employed by planners in all three cases was to try to utilize uncommitted resources. Mission planners sought solutions that would accommodate the unanticipated disrupting event separately, without disturbing the plan in progress. Options they considered included; launching uncommitted resources or obtaining additional resources from other organizations. Only when these options failed or were not available, did mission planners opt to divert an aircraft.

Once the decision had been made to divert an aircraft, planners identified suitable aircraft based on the amount of crew duty day remaining and the relative proximity to the patient. If a plane had the crew duty time available, met medical and equipment requirements, and was reasonably close to the patient, it became a candidate for diversion. Once planners identified a suitable aircraft for diversion, they embarked on a depth first strategy, seeking to commit the candidate aircraft without generating or considering other suitable options.

Once committed to a plan to accommodate the primary disrupting event, planners began to devise partial plan solutions based on the information at hand. They then moved sequentially through a series of plan refinements as new information trickled in over time reveals impasses and new constraints that threatened to render the current solution infeasible. When planners identified a constraint that could not be met, they tried to manage the constraint by either relaxing the constraint or modifying the plan at hand before abandoning it and moving on to consider a new plan. Since planners engaged in a depth first approach to replanning, when they met an impasse caused by constraints that could not be managed or negotiated, their only option was to backtrack and start the process over again to find another aircraft that could feasible accommodate the disrupting event (See Figure 6). Figure 6 clearly illustrates the depth first strategy that planners employ in the replanning process (the specifics of the model will be explained in detail in the following sections). Launching or obtaining additional resources is the first choice for planners because it provides a straight, uncomplicated path to completing a plan to accommodate the disrupting event. This path totally avoids disrupting the plan in progress. However, if additional resources are not available, it is obvious that the depth first approach leads planners down a path that can either lead quickly to plan completion, or cause planners to back track. Planners can hit impasses very far down into the planning process and be forced start the process again.

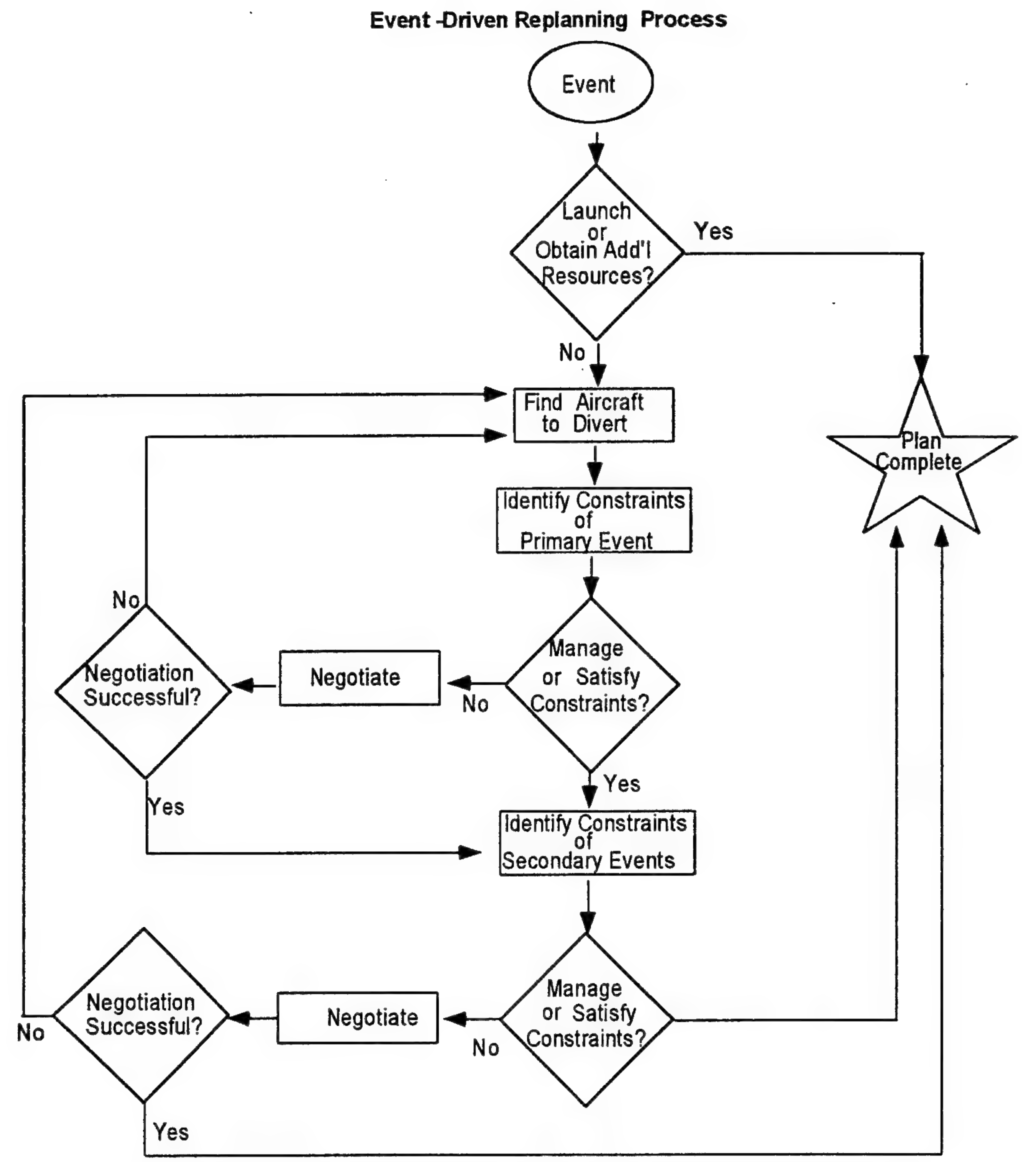


Figure 6. Model of the Event-Driven Replanning Process

Consequently, the depth first strategy is the fastest approach to successful plan implementation *provided there are no impasses or complications.* Planners' depth

first strategy is a reasonable approach given the urgency and risks associated with most unanticipated events.

Planners initially relied on recognitional or case-based processes to select the first feasible solution. When planners were able to recall past instances that were similar to the situation at hand, they were able to make decisions and devise plans more quickly and with greater confidence. When planners were confronted with situations for which they had no reference, they would first generate options prior to making planning decisions or consult a more senior member for suggestions on how to proceed. Consequently, it took longer to formulate and implement a plan when planners encountered novel situations.

In addition, an opportunistic planning approach was clearly evident during the event-driven replanning process. As planners gathered information, they were continually searching for opportunities to take advantage of resources or situations that would be to their advantage in the replanning process.

6.2.1 Strengths

Planners abilities to employ multiple planning strategies to meet the demands of the situation at hand is one of the greatest strengths of the event-driven replanning processes observed during the course of this study. Planners were able to switch, modify, combine, or devise planning strategies when they encountered bottlenecks in the planning process. The advantage to such an approach was that constraints and demands did not impede the planning

process. Planners remained constantly engaged in satisfying constraints and meeting demands. They were able to maintain a continuous flow of activity to develop a workable plan to deal with unanticipated events and their side effects. As a result, the human planner's approach to event-driven replanning was very robust in the face of the hard to satisfy constraints and the urgency of the demands that occurred in this complex and dynamic environment. Planners sought satisfactory solutions as opposed to optimal ones.

6.2.2 Weaknesses

Although a multiple strategy approach does have distinct advantages, it can become unwieldy and highly demanding when dealing with large scale planning problems. This approach becomes ineffective when planners must search large problem spaces for opportunities or past cases with similar attributes.

6.2.3 Supporting a Multi-Strategy Approach to Planning

As previously stated, current automated planning systems have been unsuccessful in complex and dynamic environments. This may be due, in part, to their inability to employ multiple strategies to meet the constraints and situations at hand. As such, automated tools should support the human planners ability to employ multiple strategies during the event-driven replanning process. Automated tools should search and prune the problem

space, characterize problems and constraints, and identify opportunities and relevant cases to augment the planners multi-strategy approach. Once the planner identifies the parameters of interest, the automated tool can search and locate the appropriate information for the planner to use as he/she sees fit.

Another method to support the recognitional/case-based strategy specifically would be for the GPMRC crew to schedule weekly or biweekly meetings to discuss/present interesting cases that have occurred during that time interval. Physicians utilize this method of learning in teaching hospitals. This would allow planners to learn from the experiences of others and increase their recognitional base.

6.3 Changing Information and Multiple Threads Cause Apparent Closures

Typical planning approaches assume a complete set of data input at the outset of the planning process. In event-driven replanning however, planners must commence the replanning process based on the data at hand. As new information comes in, it must be folded into the planning process and evaluated for possible side effects. Very often this new information spurs new activities, creates new goals and changes the mindset of the participants. Apparent closures generally resulted when new information was injected into the planning process. This new information either changed the status of tasks that were previously closed, or acted as triggers to revisit previous threads.

In addition to new information, the presence of multiple activities that intertwined and went on in parallel contributed to many of the apparent closures highlighted in the protocols. A coherent line of reasoning or activity is referred to as a thread. Threads run throughout each episode; they start up, fade away, and re-emerge. Additional threads come in and demand attention or consideration while others are ongoing.

Trying to keep track of who is managing what threads and the status of those threads can be confusing. The confusion stems not only from the fact that multiple people, distributed in various locations, must coordinate to manage the threads, but also from the fact that each individual may be responsible for managing several threads at a time. As individuals jumped from one thread to the next, they lost situation awareness and had to reorient themselves to the threads at hand. This sometimes created situations where tasks were reopened after they appeared to be closed.

6.3.1 Weaknesses

Human information processing capabilities are limited. In the cases previously described, planners had a difficult time keeping track of the threads associated with reacting to *one* unanticipated event with limited side effects. In addition, planners were operating in a peacetime environment with relatively low patient loads and abundant resources. Imagine the number of threads that would be involved in handling a mass casualty situation with multiple side

effects, in a resource limited environment. Planners would be saturated almost immediately as they tried to manage and track the various threads that would exist in such a scenario.

Ultimately, the apparent closures that result from changing information and managing multiple threads can lead to plan degradation, plan delay, or plan failure.

6.3.2 Supporting Changing Information and Managing Multiple Threads to Alleviate Apparent Closures

To alleviate the potential problems associated with changing information and managing multiple threads, a support tool should assist planners by providing a record of incoming information and highlighting those threads that are critical to plan development or require immediate attention. In addition, providing a central repository for information can provide a means for team members to know the status of activities in the planning process This tool must provide common visibility and access to all participants, wherever they may be. The tool should be open and show the constraints that have been identified and the status of the process of meeting those constraints. In addition, it should participants to make annotations on the common viewing space. The tools should support the cooperative nature of the process.

6.4 Satisfying and Relaxing Constraints: The Role of Negotiation

An integral part of the planning process is the ability to identify and manage constraints. Constraints drive the event-driven replanning process. In part, constraints are an element of planners' knowledge of their tasks. For instance, whenever planners began the search for a plane to divert, they also checked on an appropriate landing site. They knew the constraints of their resources and naturally folded that information into the planning process.

Very often however, new information comes in that presents additional constraints that planners had not anticipate. In most cases the disrupting event and subsequent secondary disruptions are accompanied by constraints that planners must satisfy in order to implement a plan successfully. Planners satisfy constraints by managing them or by relaxing them. Managing constraints involves finding ways to deal with the constraining elements. For instance, searching for a suitable landing field is a way to manage the weight constraints of particular aircraft. Relaxing constraints, on the other hand, involves removing or modifying the constraining elements. For example, in Case 1, waiving the heart monitor requirement removed the need for a cardiac attendant. In Case 3, planners considered turning the monitoring equipment off during take-off and landing to avoid the potentially constraining EMI effects during critical phases of flight.

Negotiation is a critical and necessary component of constraint relaxation and the overall event-driven replanning process. As presented in Figure 7,

negotiation plays a key role in the stepwise approach to accommodate disrupting events and institute a satisfactory revised plan. In addition, negotiation is an inherently cooperative activity that requires multilateral communications between participants distributed in multiple locations, sharing and exchanging information and ideas. The cooperative nature of negotiation is the result of information that resides with by multiple individuals who must coordinate to decide and act to carry out the event-driven replanning process.

6.4.1 Strengths

The planners' ability to manage and relax constraints via negotiation is a major strength in his/her ability to perform the event-driven replanning process. Knowledge of the system and the people that operate within the system enable planners to identify the flexible boundaries that may be candidates for negotiation. Favors owed and friends in key places contributed to the planners' abilities to negotiate constraints and devise new plans in the cases observed in this study.

6.4.2 Weaknesses

The manual approach to the negotiation process may be difficult to manage when there are multiple constraints or tasks to deal with particularly during scaled-up operations. In addition, the inherently cooperative nature of negotiation is susceptible to all of the shortcomings of shared tasks. Since

negotiation is reliant on the participants ability to communicate, disrupted lines of communication can create major bottlenecks and potential failures in the negotiation process.

6.4.3 Supporting Negotiation

Supporting negotiation is critical to effective event-driven replanning. As such, supporting negotiation is inherently a process of supporting cooperative work. Tools to support this activity must be very flexible, adaptable and provide mechanisms that allow participants to identify and discuss tradeoffs. Techniques could include; identifying constraints that have flexible boundaries, using "fuzzy" logic that would enable planners to have flexible control of parameters, and generating options to help planners stack chits to use in the negotiation process.

6.5 Managing vs. Minimizing Cascading Secondary Disruptions

A significant amount of the planning activity centered around handling secondary disruptions that resulted from decisions to utilize previously committed resources. Diverting aircraft that were part of a plan in progress produced side effects that rippled throughout the planning process. Not only were original plans disrupted, but plans for missions days into the future also had to be modified in order to accommodate the changes required to satisfy the unanticipated event.

Managing secondary disruptions could entail switching crews, arranging new equipment requirements, etc. In addition, secondary disruptions necessitate additional coordination, bring more participants into the process, widen the distribution and coordination network, and ultimately increase the number of potential failure points in the process. Taking into account all of the additional work and potential problems associated with managing secondary disruptions, it was assumed that planners would try to minimize the number of secondary disruptions. Consequently, the initial hypothesis was that planners would explicitly considered minimizing number of secondary disruptions as they sought solutions to the primary disrupting event. Surprisingly however, observations and results of the protocol analysis did not support this hypothesis. Potential secondary disruptions were not explicitly considered as part of the equation for determining which plane to divert. Instead, planners used primarily a depth first planning strategy to satisfy the primary disrupting event opting to manage the secondary disruptions that ensued. This approach is very similar to the abstraction hierarchy plan generation process described by Sarcedoti (1974). Like the abstraction hierarchy, planners identify the top level plan for dealing with the primary disrupting event and consider the secondary disruptions as details to be handled at lower stages of the planning process.

6.5.1 Strengths

One of the primary reasons why planners may engage in this seemingly inefficient planning approach is that the majority of the primary disrupting events have a compelling sense of urgency attached to them. When a patient's status is classified as Urgent, it means deal with that patient AS SOON AS POSSIBLE , regardless of the 8 hour time window specified in the regulations. During the course of this research, there were several instances where GPMRC could not provide transportation RIGHT NOW. In cases where GPMRC was unable to provide immediate transport (typically within 2 hours maximum), Urgent Patients were sent to local civilian hospitals to receive the appropriate medical care. As a result, planners focus on satisfying the new demand exclusively rather than seeking solutions that will inclusively accommodate the new demand, secondary disruptions, and planner workload. Given the urgency of many of the unanticipated disrupting events, this is in fact a rational approach under the circumstances.

6.5.2 Weaknesses

One of the primary weaknesses with this approach is that it can prove costly when secondary disruptions are significant. This was what happened in Case 2 when a secondary disruption proved to be more than a "detail" to be handled. Consequently, planners were forced to backtrack and revise their plan.

Another potential weakness might be the planners' abilities to manage a large number of secondary disruptions. In the cases observed, planners did a fair job of managing secondary disruptions; however, it was apparent that they were indeed challenged by the small scale disruptions that were encountered. Consequently, if one or two disruptions were problematic, what would happen in a mass casualty situation? Obviously planners would be quickly overwhelmed and planning would suffer as a result.

6.5.3 Supporting the Management of Secondary Disruptions

Planners need a visualization tool that would allow them to see the spreading effects of diverting aircraft and changing itineraries. In addition, the availability of more breadth of options would save time by decreasing the amount of backtracking required to enact a viable plan. A computer could be used to generate options that satisfy the new demand exclusively or take other factors into consideration, such as minimizing secondary disruptions. However, it should be noted that consideration of secondary disruptions may only be relevant with respect to anticipating potential impasses as a means to identify constraints and highlight those areas where constraint relaxation and negotiation may occur. and not minimizing secondary disruptions despite their cost. In any case. computer generated options must be equally satisfactory with regard to accommodating the new demand.

6.6 Collaborative Projection

There was evidence that planners utilized a planning preview process much like a visualization tool that will be referred to as "collaborative projection" during each of the cases observed. Collaborative projection occurred as planners tried to determine the activities required and the potential bottlenecks to overcome in accommodating the primary disrupting event (planners did not look ahead in order to minimize the cascade of secondary disruptions). Collaborative projection was used to step through certain aspects of the proposed plan much like Klein's mental simulation. During mental simulation, an individual consciously enacts a sequence of events in an attempt to envision how a situation will evolve (Klein & Crandall, 1995). Like mental simulation, collaborative projection was used to develop expectancies and detect potential bottlenecks. The primary distinguishing factor between mental simulation and collaborative projection however, is that while mental simulation is a process that occurs in the mind of an individual, collaborative projection is an activity that is distributed across individuals as they simulate portions of a plan and then collectively construct the overall proposed plan sequence. Each member of the team walked through the steps their particular areas of responsibilities to determine requirements and anticipate bottlenecks. For instance, the FCC projected aspects of the plan related to patient care and supporting the MCD. The DO projected mission requirements such as crew

duty time, landing requirements, clearing customs, etc. The CTL simulated coordinating with the various AECs and ground transportation requirements. The CP projected the flight calculations and clearances required and the information that would have to be passed on to the flight crew. Each team member knew their area of responsibility and consequently engaged in mental simulation to walk through the details of their portions of the plan.

Whenever a team member encountered an potential bottleneck or situation that needed further attention, this information was shared with the group so that a solution could be determined or others could adjust their prospective mental pictures to incorporate this new information.

6.6.1 *Strengths*

The socially distributed cognitive nature of collaborative projection produces plans that are more robust than those created by individuals. The distributed simulation process provides multiple perspectives of the problem space and lessens the probability that data will be missed or relevant information left out. Having multiple perspectives also guards against potential fixation errors (DeKeyser & Woods, 1990).

6.6.2 *Weaknesses*

Since this is a collective process, if one team member's projection (i.e. their assessment and simulation of their respective area) is in error, they can affect

everyone else's image and ultimately distort the replanning process if the error goes undetected. For example, if a controller projects an image in which he has coordinated ground transportation for a particular time, the FCC and the DO will respond to that information and project coordination with the flight crew, AEC, and medical crews for that time. If the controller errs with respect to the projected transportation time, a mismatch would exist between the GPMRC's expectations and reality an a plan-goal mismatch would result (Hammond, 1991).

6.6.3 Supporting Collaborative Projection

A tool that supports collaborative projection must be able to respond to multiple inputs to maintain the socially distributed cognitive process. It should provide an open visualization tool that will allow all team members to view a composite image of the status of the replanning process from which they can modify their individual projection until a coherent picture emerges. New information will cause one or more of the individual projections to become unfocused prompting team members to modify or re-tune their particular portion of the replanning activity to regain the coherent common image. Collaborative projection is an interesting phenomenon that warrants further study to explore in depth how it is carried out and how to enhance this seemingly naturally occurring process.

6.7 Conclusion

Event-driven replanning is much more complex than simple plan generation or static plan repair. Event-driven replanning is dynamic - resources are committed, wheels are turning, people are moving, and planes are flying. It is a multifaceted process that requires the ability to solve problems, manage disruptions, and make decisions to accomplish the task. The aeromedical evacuation is an environment that compounds the complexity of the process because it, like many other complex scheduling and planning processes, is physically and functionally distributed across multiple participants.

The cases observed during this study provided a natural laboratory to study the cognitive issues involved in military aeromedical evacuation planning.

In order to support the event-driven replanning process, tools must be designed to augment the planner's ability to manage multiple issues that arise during the planning and replanning process. In addition, any such tool must provide adequate flexibility to allow tradeoffs and negotiations to take place. Only if these activities are supported can computer tools in this environment expect to succeed as decision making aides. It is hoped that the information obtained in this research can be used to design more effective automated tools to support the complex event-driven replanning process. Supporting event-driven replanning is much more than simply designing complex scheduling algorithms, automated solution generators, or computer tools to support a single individual. It's about designing tools to support the inherently cooperative nature of key

aspects of the event-driven replanning process. It's about computer supported collaborative work (CSCW). Studying the event-driven replanning process in the current aeromedical evacuation system indicates that perhaps the smartest approach to aiding the replanning process may come through CSCW) tools.

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